Connecting People With Ecosystems in the 21st Century:

An Assessment of Our Nation's Urban Forests

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Abstract

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Urban areas (cities, towns, villages, etc.) cover 3.5 percent of the 48 conterminous states and contain more than 75 percent of the population. In urban areas, about 3.8 billion trees cover 27.1 percent of the land. On a broader scale, metropolitan areas (urban counties) cover 24.5 percent of the conterminous United States and contain 74.4 billion trees that cover 33.4 percent of these counties. Between 1950 and 1990, metropolitan areas nearly tripled in size; urban areas doubled in size over the past 20 to 25 years.

This report is the first national assessment of urban forest resources in the United States and details variations in urbanization and urban tree cover across the United States by state, county, and individual urban area. It illustrates local-scale variation, complexity, and connectedness of the urban forest resource and how this resource changes through time in response to a wide range of powerful forces. The report concludes by outlining future areas of emphasis that will facilitate comprehensive, adaptive, and sustainable urban forest management and improve environmental quality, enhance human health, and connect people with ecosystems in the 21st century.

Keywords: Urban forests, urban forestry, tree cover, sustainability, adaptive management, urbanization, urban ecosystems, urban populations, metropolitan areas, RPA assessment.

Summary

People are having an ever increasing impact on local, regional, and global environments. This is particularly significant in and around urban areas, where people are often physically or psychologically disconnected from more natural ecosystems. Urban forests and forestry can provide significant benefits to the U.S. population and have the potential to help reconnect the urban population with natural resources and their management. This report is the first national assessment of urban forest resources in the United States. It provides a basis to help develop comprehensive management plans to sustain the urban forest resource and improve environmental quality, enhance human health and well-being, and connect people with ecosystems in the 21st century.

The Urban Forest Resource of the Conterminous United States

Urban forests are a significant national resource that promise to increase in extent and importance in the years ahead. Metropolitan areas (urban counties) represent the broadest extent of urbanization in the country, including 24.5 percent of the total area and roughly 80 percent of the total population in the 48 adjacent United States. With an average tree cover of 33.4 percent, metropolitan areas collectively support nearly one-quarter of the Nation's total tree canopy cover—some 74.4 billion trees. Trees found in urban areas (cities, towns, and villages) also comprise a substantial portion of the Nation's resource base. Covering 3.5 percent of the total area and containing more than 75 percent of the total population, urban areas support trees that account for 2.8 percent of the total tree canopy cover in this country—about 3.8 billion trees. The average percentage of tree canopy cover for both metropolitan areas (33.4 percent) and urban areas (27.1 percent) is close to that for all land in the conterminous United States (32.8 percent), thereby demonstrating that urban areas and urban influence can coexist with a significant tree canopy.

The urban forest resource differs in extent across the United States. The Northeast is the most urbanized portion of the Nation; 9 of the 10 states with the highest proportion of urban land occur in this region. States with the highest proportion of their total tree cover in urban areas include New Jersey (22.3 percent), Massachusetts (14.4 percent), and Connecticut (14.0 percent) (table 1). States with the largest urban tree populations are generally in the South and Northeast and include Georgia (232.9 million urban trees), Alabama (205.8 million), and Ohio (191.1 million) (table 1). The surrounding natural environment has a significant impact on the urban forest resource and its management. Cities that developed in forested areas average 34.4 percent tree cover; cities in grasslands, 17.8 percent; and cities in deserts, 9.3 percent.

States with the greatest absolute population growth per unit of land between 1990 and 1996 are in the East: New Jersey (13.4 people per square kilometer), Delaware (11.6), Maryland (11.5), Florida (10.5), Georgia (5.8), and North Carolina (5.5). States with the greatest percentages of increase in population (1990-96) are in the West: Nevada (33.4 percent), Arizona (20.8), Idaho (18.1), Utah (16.1), and Colorado (16.0). Between 1950 and 1990, metropolitan areas nearly tripled in size; urban areas doubled in size between the late 1960s and early 1990s.

As urban development continues to expand over the landscape, the relation between urban growth, urban influence, and natural resource systems will become increasingly important. Many cities, particularly in the Southeastern United States, are surrounded by forest land. The expansion of these cities likely will have a significant impact on the extent, use, and management of forest resources. As urbanization spreads into less developed rural areas, a growing percentage of the Nation's natural resources will become part of urban forest ecosystems, and increasing amounts of forest outside these systems also will be subject to urban influence.

Table 1—Estimated number of urban trees, tree cover, and urban area, by state, in the conterminous United States

State	Urban trees	Urban trees/ capita	Urban tree cover	Portion of state tree cover	Urban area[a]	Portion of state
			– – – – *Percent*	– – – –	*Km²*	*Percent*
Georgia	232,906,000	49	55.3	4.7	8,338	5.4
Alabama	205,847,000	69	48.2	4.7	8,487	6.3
Ohio	191,113,000	22	38.3	7.0	9,923	8.5
Florida	169,587,000	13	18.4	5.5	18,407	10.8
Tennessee	163,783,000	49	43.9	5.1	7,382	6.8
Virginia	156,545,000	27	35.3	4.9	8,869	8.0
Illinois	155,544,000	14	33.7	5.5	9,165	6.1
California	148,612,000	5	10.9	2.2	27,348	6.4
New Jersey	143,869,000	20	41.4	22.3	6,916	30.6
Texas	140,709,000	8	10.5	3.6	26,573	3.8
Pennsylvania	139,020,000	16	34.4	4.2	8,363	7.0
North Carolina	138,606,000	36	42.9	3.4	6,419	4.6
New York	132,466,000	8	26.3	3.5	10,127	7.2
Minnesota	127,767,000	33	37.4	2.2	6,775	3.0
Michigan	110,858,000	17	29.7	1.6	7,494	3.0
Montana	108,550,000	251	49.4	2.2	4,365	1.1
Washington	93,272,000	23	33.6	2.0	5,679	3.1
Maryland	89,434,000	21	40.1	11.1	4,525	14.1
Missouri	87,148,000	21	30.6	2.3	5,655	3.1
Massachusetts	86,829,000	17	25.3	14.4	6,893	25.2
South Carolina	86,696,000	44	39.8	3.6	4,380	5.3
Indiana	78,498,000	21	31.2	4.2	5,000	5.3
Maine	68,550,000	110	47.7	2.2	2,887	3.1
Louisiana	68,510,000	19	25.3	2.4	5,374	4.0
Mississippi	65,520,000	48	38.6	1.8	3,365	2.7
Wisconsin	59,344,000	18	25.8	1.5	4,565	2.7
Oklahoma	58,204,000	16	14.5	3.6	7,940	4.4
Kentucky	56,681,000	23	33.4	1.9	3,374	3.2
Arizona	53,950,000	9	11.4	2.4	9,218	3.1
Iowa	52,474,000	29	33.1	1.9	3,148	2.2
Connecticut	44,800,000	14	21.8	14.0	4,085	28.5
Arkansas	43,412,000	32	25.0	1.5	3,435	2.5
New Hampshire	41,455,000	60	49.1	4.6	1,678	6.9
Oregon	34,583,000	17	30.4	.6	2,280	.9
Colorado	28,149,000	7	13.0	.8	4,345	1.6
Kansas	26,677,000	17	20.5	2.9	2,575	1.2
West Virginia	22,871,000	33	42.2	.9	1,086	1.7
Utah	18,330,000	9	14.0	1.0	2,577	1.2
Nevada	15,834,000	9	9.9	.8	3,195	1.1
Delaware	13,257,000	27	46.3	9.0	566	8.8

Table 1—Estimated number of urban trees, tree cover, and urban area, by state, in the conterminous United States (continued)

State	Urban trees	Urban trees/ capita	Urban tree cover	Portion of state tree cover	Urban area[a]	Portion of state
			---- *Percent* ----		*Km²*	*Percent*
Idaho	12,494,000	18	25.6	.3	966	.4
Nebraska	11,243,000	10	21.1	.9	1,061	.5
Vermont	7,558,000	42	36.0	.8	416	1.7
South Dakota	6,007,000	15	19.2	.5	617	.3
New Mexico	5,682,000	4	4.8	.3	2,316	.7
Rhode Island	4,155,000	5	8.9	6.0	926	23.2
North Dakota	1,774,000	5	7.8	.2	457	.2
Wyoming	1,392,000	3	3.6	.1	797	.3
Total, United States[b]	3,820,491,000	17	27.1	2.8	281,000[c]	3.5

[a] Includes land and water.

[b] U.S. total includes the District of Columbia, but not Alaska and Hawaii.

[c] Includes 492 square kilometers that crossed state borders and could not be assigned to an individual state.

The expansion of urban and metropolitan areas has particularly important implications for the use and management of public holdings, including National Forests, National Parks, and state and locally administered natural resources. Because urban residents frequently travel to exurban areas for outdoor recreation, the demands placed on forest ecosystems close to growing urban centers pose difficult challenges to natural resource managers. Heightened resource use, increased mobility or ignition of potential hazards (for example, insects and disease, invasive species, and fire), conflicts regarding recreational opportunities, and seasonal and permanent home development can greatly complicate the issues that must be addressed to protect the health and sustainability of these valuable areas.

In addition to human impacts on natural resource systems, urban forests and forestry affect human populations. By enhancing the contributions of urban vegetation to air and water quality, energy conservation, recreational opportunities, and community well-being, urban forestry provides an opportunity to integrate environmental stewardship with social progress. The involvement of urban residents with urban forests and forestry often influences their perceptions and behaviors concerning forests and forestry in exurban areas.

Complexity of the Urban Forest Resource at the Local Scale

The Nation's urban forest resource is large, growing, and variable within and among different regions of the country. Management of urban forest occurs largely at the local, city-specific scale, where the complexity of the urban forest ecosystem is most evident. Tree and ground cover, buildings, infrastructure, wildlife, and human populations all contribute to the diversity of urban forests. These components interact across the urban ecosystem through complex, interwoven relations.

Amount and types of tree cover differ considerably within urban systems and play different roles in affecting the local human population and environment. Along with the surrounding natural environment, two important factors affecting the urban forest at the local scale are land use distribution and the amount and type of vegetation management activities. Land use establishes the surrounding activities and space for vegetation, and management determines the amount of direct human manipulation of the vegetation system. Land uses with the highest percentage of tree cover are typically park and residential areas and vacant land in cities within forest ecotypes. Land uses with the lowest percentage of tree cover are typically commercial and industrial areas and vacant land in cities within desert ecotypes.

Different vegetation configurations across a range of land uses interact with each other, humans, and the physical environment to create a complex system affecting social well-being and functioning. The connections among vegetation configurations on different land uses at the local level, and between urban and rural vegetation configurations at the regional scale, can affect the movement of wildlife, people, insects, and diseases and the distribution of social and physical benefits provided by alternative vegetation structures.

Comprehensive studies in Chicago and Oakland highlight substantial variation in the extent, distribution, and condition of urban forest resources across different land uses and among locations within the urban system. The diversity of urban systems can complicate vegetation management because of the multiple connections among vegetation and components of the physical environment and social-economic systems. When we understand the common features of vegetation structure, human preferences, and management activities on different land uses, as well as how the different vegetation structures link within urban areas and across the urban-to-rural gradient, integrated and comprehensive management plans can be developed to enhance local and regional forest benefits.

Changes in Urban Forests Through Time

The structure of the urban forest changes through time in response to a wide range of powerful forces. These changes originate from diverse human and natural actions operating directly and indirectly on the urban forest and its management. The impacts of these forces for change vary over time and across and among urban systems; they contribute to different urban ecosystems and rates of change across urban areas. By understanding how human and natural forces interact within urban systems to create change, management can minimize negative forest changes and facilitate positive changes. Human forces for change in urban forests include:

- Urban resident involvement in tree planting, maintenance, and management
- Plant community and species preferences or fads
- Influx of funds to plant trees and other vegetation
- Management of urban infrastructure
- Urban development and land use change
- Development of new urban forest management techniques and tools
- Increased interest in quality of the urban environment and urban life
- Changing character of the urban population (race, ethnicity, and age structure)
- Byproducts of urbanization (for example, air and water pollution)

Natural forces that can lead to changes in urban forest structure include:

- Extreme precipitation or temperature events
- Storms and other natural disasters
- Fire
- Natural regeneration
- Aging of the existing forest
- Insect and disease outbreaks

What most distinguishes the urban forest from exurban forests is the dynamic influence of people. Human activities not only change urban forest structure to meet design and functional needs but also try to minimize and prevent detrimental changes due to natural forces (for example, controlling insects and diseases or altering structure to reduce the risk of wildfires) to sustain desired forest structure. Given the inherently slow development of trees amid rapidly changing urban environments, human forces for change pose significant challenges for natural resource planning and management in urban areas.

A combination of human actions and natural forces will continue to shape the urban forests in the years ahead. These interacting forces highlight the need to coordinate urban forest resource management with many other urban activities (for example, land use planning, environmental protection, residential development, infrastructure development and maintenance, community empowerment and revitalization, and environmental education). Management of these complex, dynamic systems requires involvement of many disciplines, organizations, owners, users, and managers to sustain ecosystem health and desired functions.

Opportunities for Improving Urban Forest Resource Management

A principal goal of urban forestry is to sustain forest structure, health, and benefits throughout the urban ecosystem over the long term. Comprehensive and adaptive management approaches are needed to do this. Expanding the management focus of urban forests to all trees, associated resources, and their benefits across the urban ecosystem will require nontraditional urban forest management techniques. The overall societal benefits of implementing such management are likely to be substantial.

Management also must be comprehensive in terms of its process, and it must be adaptive to allow for adjustments in management activities based on new situations and information. To attain comprehensive and adaptive management, urban forest managers should consider:

- The desires and needs of the community
- What urban forest structure is necessary to best address community needs
- Periodically reassessing community needs and urban forest structure to ensure that management plans remain appropriate

To facilitate comprehensive and adaptive management to sustain the entire urban forest ecosystem, the following topic areas need to be emphasized:

- Improving inventory and assessment
- Improving dialogue among owners, managers, and users
- Fostering collaboration among agencies and groups

- Improving the understanding of how forest configurations influence forest use and benefits
- Increasing knowledge about factors that influence urban forest health
- Improving the dissemination of information about urban forests and their management

With improvements in the above areas, urban forest resources can become a more highly valued component of large-scale and long-term environmental and community planning.

Facilitating the effective management of urban forest ecosystems in the United States requires forging partnerships and collaborative efforts across resources, disciplines, organizations, and geographic areas. One continuing issue is to understand the relation between the management of urban and exurban resources, such that collaborative management efforts across these areas can be fostered.

Given the significance of urban forests to the overwhelming majority of the U.S. population, as well as the implications of improved and coordinated natural resource management across the urban-to-wilderness spectrum, efforts to incorporate comprehensive and adaptive strategies into urban forest management policies and plans likely will generate a substantial return on the investment. This assessment is the first step in developing a comprehensive understanding of the national urban forest resource and can assist in development of comprehensive adaptive management plans in both urban and exurban environments. As an increasingly urban population continues to play a key role in the social and political structure of the United States, understanding and managing of urban forest resources will be a critical mechanism for improving forest benefits and connecting people with ecosystems in the 21st century.

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Chapter 1: Introduction and Overview

People are having an ever increasing impact on their local, regional, and global environments. This impact is particularly significant in urban areas, where concentrated human development fragments and transforms natural resources, thereby resulting in large-scale environmental consequences. Urban forests are characterized by the integration of natural resources with human developments. In these situations, vegetation often has substantial environmental, social, economic, and historical value. This report is the first national assessment of urban forest resources in the United States. It provides information on the extent and character of urban forests in this country and serves as a template for future assessments of the urban forest resource. This assessment was developed to help guide urban forest management policies and programs aimed at improving environmental quality, enhancing human health, and connecting people with ecosystems in the 21st century.

The Urban and Community Forestry RPA Assessment

The Forest and Rangeland Renewable Resources Planning Act (RPA; 1974) was enacted to provide a vehicle for assembling important information to guide natural resource management in the Nation's forests and grasslands (Cubbage and others 1993). The motivation for using the RPA to address resource management issues was the idea that a national "fact-finding" campaign would provide a solid knowledge base for large-scale planning activities to manage the Nation's natural resources. The act calls for the Forest Service to produce (1) an assessment of "the current and expected future conditions of all renewable resources in the Nation," and (2) "a program of Agency actions that respond to the future as depicted in the assessment" (USDA Forest Service 1989). The RPA requires the Forest Service to submit an inventory of the Nation's natural resources every 10 years and to develop a related program proposal for managing the Nation's natural resources every 5 years (Cubbage and others 1993, USDA Forest Service 1989).

Past Forest Service RPA assessments have not focused on natural resources in urban areas; however, growing recognition of the significance of urban natural resource issues and their links to other urban and environmental issues has generated an increasing public interest in the extent, trends, functions, uses, and management of natural resources in urban settings. Several important groups, including the Forest Service, other Federal agencies, state agencies, private tree care firms, and not-for-profit groups have begun to give increased attention to urban natural resource issues.

The objectives of this report are to establish a definition of the Nation's urban forest, characterize and assess the extent of the resource, investigate policy and program implications, and present ideas for topics to be examined in future assessments. As the first assessment, this effort focused primarily on quantifying and describing the urban forest and its resource components. This assessment can serve as a baseline for evaluating change in the urban forest over time. The assessment was not intended as an appraisal of urban forest health, benefits, economic value, or current management policies and practices. Rather, the report lays the groundwork for continuing assessments by defining the context for future studies of these topics.

Establishing the Scope of the Assessment

The urban forest resource cannot be effectively assessed without clearly delimiting its extent. Urban forests are ecosystems characterized by the presence of trees and other vegetation in association with people and their developments. Although people and developments influence forests across the country, urban forests are located where human influences are concentrated (cities, towns, and villages). The fundamental definition of either an urban or metropolitan area is a place with a much higher population density than elsewhere (Mills and Hamilton 1984). Thus, areas must exceed a specified human population level or density to be classified as urban. Definitions of urban that have been developed by the U.S. Bureau of the Census and the Office of Management and Budget, and are recognized by Federal, state, and local agencies, are used in this assessment. This mechanism of delimiting urban areas not only captures the extent of what is commonly viewed as the urban forest but also facilitates interagency data exchange and analysis of change in the resource over time.

National Significance of Urban Forests and Forestry

Urban forests can improve environmental quality, enhance individual and community well-being, provide a wide range of services to individuals and communities, and produce a more healthful and comfortable environment for the vast majority of the U.S. population. Knowledge of the potential significance of urban forests is expanding rapidly as research continues to document the important role that urban forests can play in improving the quality of urban life. Consequently, urban residents may be able to look to urban forests and associated management programs for an increasing spectrum of important benefits in the years ahead.

Through appropriate planning, design, and management, urban forests can be designed to mitigate many of the environmental impacts of urban development by moderating climate, reducing building energy use, absorbing ultraviolet radiation and atmospheric carbon dioxide, improving air quality, lowering rainfall runoff and flooding, and reducing noise levels (for example, Heisler 1986, Heisler and others 1995, McPherson and others 1994, Nowak and others 1998). In addition to affecting the physical and biological environment, urban forests can positively influence the social and economic environment of a city. These influences can range from altered aesthetic surroundings and increased property values to a stronger sense of community and a greater connection between people and the natural environment (for example, Dwyer 1991, Dwyer and others 1992, Schroeder 1989, Ulrich 1986). Forests can turn city blocks into special places—places for residents to recreate, to gather with family and friends, and to care about.

The effects of the urban forest on the physical, biological, and social environments can ripple from the inner city to the farthest reaches of wilderness. The quality of the air, and both the quality and quantity of the water leaving urban areas, can affect the attributes of exurban areas. The quality of the urban environment also can influence the motivation of urban residents to experience exurban areas. The nature of the urban environment plays an important role in people's perceptions of, interest in, and use of forests, as well as their participation in natural resource management.

The urban forest may be the only forest that some urban residents will ever experience. Thus, urban forests can provide a context for the values that urbanites place on forests in general. Vice President Gore[1] communicated the importance of forest resources in urban areas across the United States when he remarked, "Most of us can't afford to travel to Yellowstone or the Grand Canyon when we want to enjoy the rich American landscape; a livable neighborhood lets you and your spouse walk through a natural ecosystem as you simply take an evening stroll down your street." For others, urban forests may be the first step in a continuum of progressively wilder environments experienced by city dwellers. Learning cross-country skiing in a local park may ultimately lead to the week-long backcountry ski trip. Experiences with urban forests, their management, and their use can influence residents' perceptions of and preferences for resource management in nonurban settings.

Urban forests and their management are particularly important components of U.S. forests and forestry because they occur where the vast majority of the human population lives, works, and recreates. Nearly 8 out of 10 Americans live in urban areas; they directly affect and are affected by urban forests. The complexity of the urban ecosystem, its wide-ranging uses, and the diversity of its residents create an outstanding laboratory for learning about interactions between people and forests, communicating with most of the country's population, and developing management strategies to meet diverse public needs while sustaining forest ecosystems. Thus, urban and community forestry can become a key component of the overall national effort to involve all citizens in effective natural resource management.

An Overview of Urban Forest Planning and Management

A fundamental premise behind the management of urban forest resources is that humans can manipulate the structure of vegetation to enhance various forest benefits. This mechanism occurs in the context of societal values (what the community wants) and ecological principles (what is ecologically possible) (Maser and others 1994). Even though researchers and natural resource professionals seem to agree that the goal of management is to maintain forest benefits through space and time, the functional definition of urban forest sustainability continues to generate significant discussion (Wiersum 1995). Several attempts to characterize and model the components of sustainable systems have been made; some researchers even outline specific criteria

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[1] Remarks by Vice President Albert Gore. 2 September 1998.; Speech given to The Brookings Institution, Washington, DC.

against which the sustainability of an ecosystem and its management may be measured (Clark and others 1997, Coulombe 1995, Gangloff 1995, LeMaster and Sedjo 1993). But, because the socioeconomic and ecological spheres of ecosystems are in constant flux (particularly those in urban environments), sustainability as the goal of management is subject to considerable interpretation and variation. Ultimately, the attributes of a sustainable urban forest—what it looks like, how it functions, and how it is managed—depend on which ecological functions and social benefits are desired, who chooses them, and at what scale these elements will be sustained (Gregersen and others 1998, Maser and others 1994, Wiersum 1995).

Given the dynamic nature of social values and the biological and physical components of the urban environment, the overlap between what is socially desirable and what is ecologically possible frequently changes—or may disappear altogether. Resource management must be flexible enough to accommodate changing management goals and newly emerging ecological information and issues. For this reason, adaptive management is commonly identified as the template for achieving sustainable urban ecosystems. This method approaches management as an experiment in which the appropriateness and effectiveness of management objectives, policies, and actions are continuously evaluated (Bormann and others 1994, Lee 1993, Maser and others 1994). Adaptive management uses new information and results from previous decisions as input to the planning and management process, thereby creating a recurrent cycle of learning and adjustment.

A framework for adaptive management of urban forest resources can be based on five interrelated factors:

Social context: The desires, concerns, attitudes, and values of community residents, organizations, institutions, and government agencies.

Management goals and objectives: Urban forest benefits and functions that the community wishes to sustain.

Means: Specific vegetation structure or management programs, or both, identified as necessary to sustain desired urban forest benefits.

Management outcome: Urban forest structure, condition, and use resulting from the implementation of management programs.

Information: Inventory and monitoring data, statistics, survey results, and research providing information about the characteristics of the resource, the relation between vegetation structure and benefits, management techniques and urban forest health, and monitoring technologies.

These five factors are connected through the process of urban forest planning and management (fig. 1). First, people and groups communicate and negotiate to determine the urban forest benefits they want to sustain, and they set funding and other resources to attain these management goals. Once the goals and budget of the community have been established, managers design the vegetation structure and urban forest programs needed to sustain the desired functions. Policies, activities, and maintenance programs are implemented. The input of information about urban forest functions, health, and management techniques is continuous throughout this process of setting goals, designing objectives, and implementing management activities. The outcome resulting from management efforts may or may not resemble the structure or program needed to sustain desired urban forest functions; managers may need to work through several cycles of monitoring, adjusting, and reimplementing before their efforts produce the desired outcome.

Although the steps taken to this point can accommodate changes in the biological or physical environment, the truly adaptive nature of this planning and management process lies in the evaluation and reevaluation of management objectives. Without this step, the management cycle may continue without regard to shifting social paradigms, and resources may be spent sustaining urban forest functions no longer desired. Besides testing hypotheses on structure-function relations, continuous evaluation of management objectives forces managers to adapt their efforts to changing attitudes and desires in the community.

The key to adaptive management is learning from the outcomes of planning and management efforts and applying new information to the cycle (Bormann and others 1994, Gregersen and others 1998, Lee 1993, Maser and others 1994). Periodic inventory of urban forest resources, functions, and management programs by the involved groups to assess change and generate new information therefore is crucial to the adaptive management method. Unfortunately, many current urban forestry efforts seem to be confined to urban tree planting, maintenance, and removal of public trees ("implementation," fig. 1). This narrow focus seems to be the result of an absence of integrated management efforts across the urban system (that is, activities are limited by jurisdictional boundaries), the scarcity of resources for planning and management (particularly funding), and a limited understanding of the potential contributions of the urban forest. Thus, a critical element in facilitating adaptive management for urban forest sustainability is to provide (1) a means (funding) to enable managers to implement management activities, and (2) a mechanism (information, management framework, and partnerships) to encourage sustainable forestry.

An Overview of the National Urban Forest Assessment

Because this assessment is the first national review of urban and community forestry under the RPA, it focuses considerable attention on generating primary information for adaptive urban forest management—assessing the urban forest resource and the associated human populations from a national perspective. With limited data in this relatively new area of research, trends in urban forest resources and their management are not easily identified. To help overcome the limited information on resource trends, significant attention was given to forces for potential change in urban forests, their management, and their use.

Other important urban forest topics were not covered in this assessment but are addressed in the literature. These topics include urban tree planting and maintenance (for example, Grey and Deneke 1986, Harris 1983, Miller 1997, Pirone 1972; also see *Arboricultural Journal* and the *Journal of Arboriculture*), the costs and benefits of urban vegetation (for example, Dwyer and others 1992, Grey and Deneke 1986, Miller 1997, Nowak and Dwyer 2000), and the roles and function of groups involved in urban forest planning and management (for example, Allen and Sherfy 1997, Ossenbruggen and Maller 1997, Piotrowski 1995).

Click here for Figure 1

Figure 1—A model of planning and management for urban forest sustainability (adapted from Bormann and others 1994, Lee 1993, Maser and others 1994).
1. Decisionmaking and budgeting: Determine type of benefits that people want from the urban forest (goals); prioritize goals; allocate resources to achieve each goal.
2. Planning and design: Develop structure or programs needed to reach desired goals.
3. Implementation: Administer management activities to achieve desired structure or program; identify criteria and indicators by which the effectiveness of management efforts may be critiqued.
4. Monitoring: Measure indicators to determine whether management efforts produce desired results.
5. Evaluation: Determine whether desired structure or program actually yielded the intended benefits.
6. Review (not illustrated): Determine whether management objectives still reflect the goals of the community; assess whether new designs or plans are needed to reach desired goals.

Chapter 2 begins with an assessment of the urban forest resource and its associated human population across the 48 adjacent states. Much of the discussion is based on an analysis of tree canopy cover over the United States along with population data from the U.S. census. Chapter 3 broadens the discussion of the urban forest beyond canopy cover and numbers of trees to include other components of the forest (for example, ground cover). The variability of the urban forest is detailed, followed by a look at the connections among resource components across the urban system. Given the limited availability of detailed data to assess the diversity and variability of urban forest resources at the national level, chapter 3 presents highlights from comprehensive studies of urban forests only in Chicago and Oakland, California, and more limited data from several other cities. Chapter 4 focuses on changes in the urban forest over time. In the absence of long-term urban forest data at the national level, the chapter summarizes findings from case studies in Oakland and Atlanta to identify the forces for change and illustrate their effects on the structure, use, and management of urban vegetation. The final chapter summarizes the results of the assessment and their implications for urban forest planning and management in the future. It presents several comprehensive and adaptive management emphasis areas for sustaining and enhancing urban forests and identifies topics for additional investigation. Several ideas for future assessments are offered to create a platform from which efforts to connect people with ecosystems and enhance the quality of urban life may continue into the 21st century.

Chapter 2: The National Urban Forest Resource

Introduction

Urban forests across the United States are a substantial and highly valued national resource. This chapter presents an assessment of urban forests and associated human populations across the 48 adjacent states. It outlines their extent, regional variation, and some recent changes. The data presented here have been compiled from various national, county, and city databases.

A key to assessing the urban forest resource is identifying the boundaries of urban areas. A major challenge in delimiting urban areas is that urban influences occur on a continuum, thereby making it difficult to identify firm boundaries. Further, urban influences often extend well beyond these perimeters.

For this assessment, areas under urban influences were classified into two separate (but sometimes overlapping) designations, both based on geographic entities recognized by the U.S. Bureau of the Census and the Office of Management and Budget: (1) urban areas (UA)—incorporated or unincorporated areas with at least 2,500 people or a population density of at least 384 people per square kilometer; and (2) metropolitan areas (MA)—a county or group of counties containing or tied to a large population center (that is, urban counties). Urban areas are areas where the population and its influences are concentrated (cities, towns, villages). Metropolitan areas include a large urban area (central city) and surrounding lands that are socially and economically linked to the central city. Both definitions are useful in assessing the Nation's urban forest resources; they allow for the integration of urban forest data with demographic, economic, and social information. A full description of these definitions and detailed methods of analysis are given in appendix 1. A summary of urban definitions used in this report is given in table 2.

Overview of Methods

Land area, water area, and population statistics for urban and metropolitan areas were obtained from the Bureau of the Census (U.S. Department of Commerce, Bureau of the Census 1992a, 1992b, 1992c). Data on percentage of tree cover for the conterminous United States[1] were derived through geographic information systems (GIS) analysis of forest cover maps and maps of census-designated entities. The forest cover

[1] For the remainder of this report, use of the term "United States" refers to the conterminous United States unless specifically stated otherwise.

Table 2—Summary of urban definitions

Term	Definition
Major terms:	
Metropolitan area (MA)	A county, or group of counties, that contains a large population nucleus as its core; can include adjacent counties that have a high degree of economic and social integration with the core
Urban area (UA)	Urbanized areas and unincorporated or incorporated places (for example, cities, towns, and villages) having at least 2,500 people
Secondary terms:	
Census-designated place (CDP)	A place without legally prescribed limits, powers, or functions
Consolidated metropolitan statistical areas (CMSA)	Multiple metropolitan statistical areas with a combined minimum population of 1 million that demonstrate strong internal economic and social links in addition to close ties with the central core of the larger area
Incorporated place	A place with legally prescribed limits, powers, or functions
Metropolitan statistical areas (MSA)	Metropolitan areas that contain either a city of 50,000 or more inhabitants or an urbanized area, and have a total population of at least 100,000 (75,000 in New England)
New England county metropolitan areas (NECMA)	County-based metropolitan areas representing the geographic extent of the city-based metropolitan statistical areas and consolidated metropolitan statistical areas in the 6 New England states
Place	A census definition of an area based on a concentration of people that has a name, is locally recognized, and is not part of any other place
Primary metropolitan statistical areas	Metropolitan statistical areas within consolidated metropolitan statistical areas
Rural place	Places located outside urbanized areas and having a population of less than 2,500
Urban place	Places located outside urbanized areas and having at least 2,500 people
Urbanized areas	Areas with a minimum population of 50,000 and a minimum population density of 384 people per square kilometer

maps were generated by the USDA Forest Service, Southern Forest Experiment Station, Forest Inventory and Analysis research unit, by applying statistical regression analysis to multitemporal 1-kilometer resolution advanced very high resolution radiometer (AVHRR) data and Landsat thematic mapper (TM) data (Zhu 1994). These tree cover data were subsequently combined with the boundaries of states, counties, and the geographic components of urban areas in a GIS to estimate tree cover within each of these designations across the United States.

Tree cover estimates developed from AVHRR data were compared with aerial photograph calculations of tree cover in selected urban areas (Nowak and others 1996) and national resources inventory (NRI) tree cover calculations for counties (USDA Natural Resources Conservation Service 1995). Comparison of AVHRR-based tree cover estimates with those developed from aerial photographs and NRI data revealed possible limitations in the AVHRR-based data that included (1) inaccuracies in certain regions of the country; (2) underestimates of tree cover in coastal cities; and (3) increased uncertainty of the tree cover estimates as the area of analysis becomes smaller, or with increasing distance from the model calibration center for each physiographic region (appendix 1).

The amount of forest land within and around urban and metropolitan areas was calculated from the USDA Forest Service forest inventory and analysis (FIA) database retrieval system (USDA Forest Service 1997a). The omission of forest land estimates for highly urban counties and the current lack of access to forest land data in certain parts of the United States limit this analysis. Because FIA inventory plots are not usually measured in urban areas, estimates of that forest land are artificially low.

Tree Cover and Population Characteristics Across the United States

Percentage of tree cover and population characteristics were assessed for all land (urban and nonurban) in the 48 adjacent states. Analyses were performed at the state and county levels.

National Tree Cover

Percentage of tree cover is highest in the Eastern United States, with the highest statewide percentages in West Virginia, New Hampshire, and Vermont. The lowest percentage occurs in the mid to southwestern region and includes Kansas, Texas, and North Dakota. Because natural vegetation types significantly influence the overall proportion of the state covered with trees, states in forested regions typically have the highest percentage of tree cover. Nationally, tree cover averages 32.8 percent (table 3).

National Population Characteristics

Population densities are highest in the Northeast and lowest in the western half of the country. States with the highest population densities in 1996 were New Jersey, Rhode Island, and Massachusetts; states with the lowest population densities in 1996 were Wyoming, Montana, and North Dakota. The average population density in 1996 across the United States was 34 people per square kilometer (table 3, fig. 2).

Analyses of 1990 and 1996 county population densities indicated that growth in population density is associated with initial population density and total county population (figs. 3 and 4). Densely populated counties (that is, population density > 192 people per square kilometer) actually exhibited a decrease in population per unit area between 1990 and 1996. This trend was due, in part, to population losses in some central city areas. Counties containing rapidly growing urban and metropolitan areas (for example, counties containing Denver, Atlanta, Daytona Beach, and Las Vegas) had the greatest increase in population density; this trend likely will continue (appendix 2).

Table 3—Overall tree cover, land and water area, land use, and population characteristics, by state

State	Tree cover	Area			Land use[b]			Total population				Race and ethnicity[e]				
		Land	Water	Fed.[a]	Agr.	For.	Urb.	1990[c]	1996	Change[d]	Dens.	W	B	NA	AP	H
	Percent	*Square kilometers*			*– – – – Percent – – – –*					*Percent*	*Per km²*	*– – – – – – Percent – – – – – –*				
Alabama	64.3	131,443	4,332	2.8	23.9	65.2	4.4	4,040,587	4,273,084	5.8	32.5	73.6	25.2	0.5	0.5	0.6
Arizona	15.3	294,333	943	41.5	78.6	11.1	2.5	3,665,228	4,428,068	20.8	15.0	81.0	3.0	5.6	1.5	18.6
Arkansas	41.8	134,875	2,867	9.4	45.7	46.3	2.5	2,350,725	2,509,793	6.8	18.6	82.7	15.9	0.6	0.5	0.8
California	31.1	403,971	20,031	45.5	52.4	27.3	8.1	29,760,021	31,878,234	7.1	78.9	69.1	7.4	0.8	9.6	25.4
Colorado	24.8	268,658	960	35.9	84.0	8.8	2.5	3,294,394	3,822,676	16.0	14.2	88.3	4.0	0.9	1.8	12.7
Connecticut	45.1	12,550	1,808	0.4	11.2	54.2	25.0	3,287,116	3,274,238	-0.4	260.9	87.1	8.3	0.2	1.5	6.2
Delaware	45.5	5,062	1,385	2.6	43.1	28.0	13.4	666,168	724,842	8.8	143.2	80.4	16.8	0.3	1.3	2.3
Florida	36.9	139,853	30,461	11.6	31.5	36.6	12.1	12,937,926	14,399,985	11.3	103.0	83.1	13.6	0.3	1.2	12.0
Georgia	63.3	150,010	3,943	5.6	25.7	60.8	7.0	6,478,216	7,353,225	13.5	49.0	71.1	26.9	0.2	1.1	1.6
Idaho	41.7	214,325	2,131	62.3	72.0	19.9	1.7	1,006,749	1,189,251	18.1	5.6	94.4	0.4	1.5	0.9	5.1
Illinois	37.8	143,987	6,021	1.4	77.5	9.5	8.0	11,430,602	11,846,544	3.6	82.3	78.4	14.8	0.2	2.5	7.7
Indiana	39.4	92,904	1,424	2.1	71.7	15.9	7.1	5,544,159	5,840,528	5.4	62.9	90.6	7.8	0.3	0.7	1.7
Iowa	37.4	144,716	1,038	0.5	87.9	5.4	2.1	2,776,755	2,851,792	2.7	19.7	96.7	1.7	0.3	0.9	1.1
Kansas	8.6	211,922	1,189	1.2	92.2	2.6	1.7	2,477,574	2,572,150	3.8	12.1	90.2	5.7	0.9	1.3	3.6
Kentucky	56.3	102,907	1,759	4.6	47.6	41.8	4.4	3,685,296	3,883,723	5.4	37.7	92.1	7.1	0.2	0.5	0.6
Louisiana	43.9	112,836	21,438	4.1	28.5	41.5	3.9	4,219,973	4,350,579	3.1	38.6	67.3	30.8	0.5	0.9	2.2
Maine	70.0	79,939	11,714	0.8	3.1	82.1	2.1	1,227,928	1,243,316	1.3	15.6	98.4	0.4	0.5	0.6	0.6
Maryland	49.1	25,316	6,818	2.5	34.6	36.7	14.0	4,781,468	5,071,604	6.1	200.3	71.0	24.9	0.3	2.9	2.5
Massachusetts	50.4	20,300	7,037	2.7	8.2	48.5	24.6	6,016,425	6,092,352	1.3	300.1	90.0	4.9	0.2	2.3	4.6
Michigan	52.0	147,136	103,329	11.8	30.9	50.7	6.8	9,295,297	9,594,350	3.2	65.2	83.5	13.9	0.6	1.1	2.0
Minnesota	50.3	206,207	18,975	7.8	53.2	27.8	2.4	4,375,099	4,657,758	6.5	22.6	94.5	2.2	1.1	1.8	1.1
Mississippi	56.9	121,506	3,937	5.8	37.0	54.9	2.9	2,573,216	2,716,115	5.6	22.4	63.5	35.6	0.3	0.5	0.6
Missouri	41.5	178,446	2,100	4.5	64.6	27.4	3.4	5,117,073	5,358,692	4.7	30.0	87.7	10.7	0.4	0.8	1.2
Montana	25.7	376,991	3,859	28.8	87.0	7.7	0.4	799,065	879,372	10.1	2.3	92.8	0.3	6.0	0.5	1.5
Nebraska	12.7	199,113	1,245	1.5	94.3	1.6	1.0	1,578,385	1,652,093	4.7	8.3	93.8	3.6	0.8	0.8	2.2
Nevada	13.5	284,396	1,971	85.2	85.6	3.4	2.8	1,201,833	1,603,163	33.4	5.6	84.3	6.5	1.7	3.2	10.1
New Hampshire	73.7	23,231	988	12.5	5.0	75.6	8.6	1,109,252	1,162,481	4.8	50.0	98.0	0.7	0.2	0.8	1.0
New Jersey	55.4	19,215	3,375	3.3	17.5	36.6	30.5	7,730,188	7,987,933	3.3	415.7	79.4	13.4	0.2	3.5	9.3
New Mexico	12.9	314,334	605	35.2	84.4	9.1	0.9	1,515,069	1,713,407	13.1	5.5	75.8	2.0	8.9	1.0	38.1
New York	54.6	122,310	18,771	0.8	29.4	52.3	9.0	17,990,455	18,184,774	1.1	148.7	74.5	15.9	0.3	3.8	12.0
North Carolina	58.3	126,180	13,217	7.4	26.9	50.7	9.0	6,628,637	7,322,870	10.5	58.0	75.6	22.0	1.3	0.8	1.0
North Dakota	11.7	178,695	4,428	4.3	91.8	1.0	0.5	638,800	643,539	0.7	3.6	94.7	0.6	4.0	0.5	0.7
Ohio	46.8	106,067	10,036	1.4	55.7	25.4	13.0	10,847,115	11,172,782	3.0	105.3	87.8	10.6	0.2	0.8	1.2
Oklahoma	17.5	177,877	3,171	2.7	76.5	16.1	2.5	3,145,585	3,300,902	4.9	18.6	82.3	7.4	8.0	1.0	2.7

Table 3—Overall tree cover, land and water area, land use, and population characteristics, by state (continued)

State	Tree cover	Area			Land use[b]			Total population				Race and ethnicity[e]				
		Land	Water	Fed.[a]	Agr.	For.	Urb.	1990[c]	1996	Change[d]	Dens.	W	B	NA	AP	H
	Percent	Square kilometers		– – – – Percent – – – –						Percent	Per km²	– – – – – – Percent – – – – – –				
Oregon	46.7	248,646	6,172	51.8	52.0	40.4	2.5	2,842,321	3,203,735	12.7	12.9	92.8	1.6	1.5	2.4	3.9
Pennsylvania	54.7	116,083	3,208	2.3	29.3	53.9	10.0	11,881,643	12,056,112	1.5	103.9	88.6	9.2	0.1	1.1	1.9
Rhode Island	35.2	2,707	1,295	0.7	7.7	49.1	21.7	1,003,464	990,225	-1.3	365.9	91.6	3.8	0.4	1.8	4.4
South Carolina	57.6	77,988	4,914	5.8	24.1	57.9	7.2	3,486,703	3,698,746	6.1	47.4	69.1	29.8	0.3	0.6	0.8
South Dakota	12.9	196,571	3,174	5.9	92.5	1.2	0.6	696,004	732,405	5.2	3.7	91.6	0.5	7.2	0.5	0.8
Tennessee	58.6	106,758	2,400	5.1	42.4	45.2	6.2	4,877,185	5,319,654	9.1	49.8	83.0	15.9	0.3	0.6	0.6
Texas	11.0	678,358	17,318	1.9	85.8	5.9	3.6	16,986,510	19,128,261	12.6	28.2	75.3	11.9	0.4	1.9	25.3
Utah	16.8	212,816	7,086	65.5	68.3	8.7	2.2	1,722,850	2,000,494	16.1	9.4	93.9	0.6	1.4	1.9	4.8
Vermont	73.3	23,956	947	6.0	17.4	71.5	3.7	562,758	588,654	4.6	24.6	98.6	0.4	0.4	0.5	0.7
Virginia	58.1	102,558	8,234	8.7	27.3	55.1	7.5	6,187,358	6,675,451	7.9	65.1	77.5	18.8	0.3	2.6	2.5
Washington	49.7	172,445	12,226	28.7	45.9	41.6	4.5	4,866,692	5,532,939	13.7	32.1	88.6	3.0	1.7	4.3	4.2
West Virginia	78.9	62,384	375	7.7	18.1	73.6	3.4	1,793,477	1,825,754	1.8	29.3	96.2	3.1	0.2	0.4	0.4
Wisconsin	46.8	140,672	28,971	5.3	44.0	37.7	6.4	4,891,769	5,159,795	5.5	36.7	92.3	5.0	0.8	1.1	1.8
Wyoming	17.0	251,501	1,848	47.6	90.8	3.0	0.7	453,588	481,400	6.1	1.9	94.2	0.7	2.2	0.6	5.5
United States[f]	32.8	7,665,212	415,492	20.8	61.1	26.3	4.5	247,051,601	263,349,053	6.7	34.4	80.6	12.1	0.8	2.6	8.8

[a] Percentage of state area that is Federal land (USDA Natural Resources Conservation Service 1995).

[b] Percentage of state area (non-Federal area) used for agricultural purposes, including horticultural, row crops, close-grown crops, hayland, rangeland, and pastureland (Agr.); forest, including grazed and ungrazed (For.); and urban and built-up areas (Urb.) (USDA Natural Resources Conservation Service 1995).

[c] 1990 and 1996 population (U.S. Department of Commerce, Bureau of the Census 1992c, 1997).

[d] Percentage of change from 1990 to 1996.

[e] Percentage of total 1990 population that is white (W), black (B), Native American (NA), Asian-Pacific islander (AP), and of Hispanic origin (H) (U.S. Department of Commerce, Bureau of the Census 1992c).

[f] Includes the District of Columbia, but not Alaska and Hawaii.

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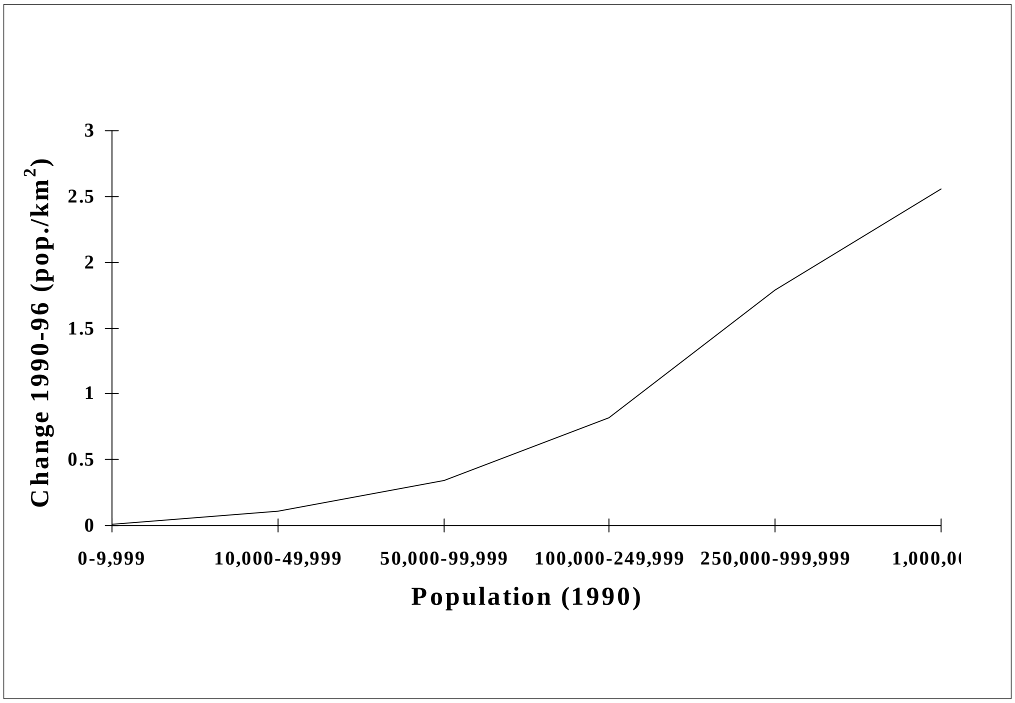

Figure 3—Relation between change in population density (1990-96) and county population.

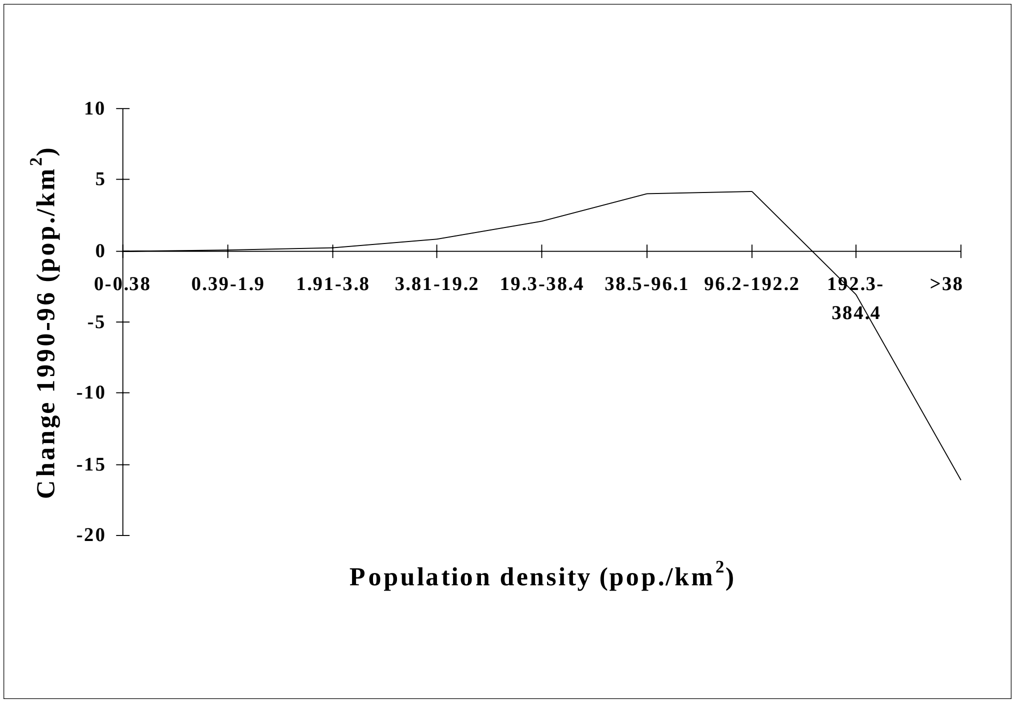

Figure 4—Relation between change in population density (1990-96) and 1990 county population density.

Between 1980 and 1996, the South[2] had the greatest average annual increase in population (704,000/year), followed by the West[3] (539,000/year), the Midwest[4] (54,000/year), and the Northeast[5] (-28,000/yr) (U.S. Department of Commerce, Bureau of the Census 1998a). The population in the Midwest decreased between 1980 and 1984 but has increased since 1985. Between 1990 and 1996, most counties in the United States increased in population, with the greatest percentages of increase occurring in the West, South, and some rural areas in other regions with high recreation and amenity value (fig. 5). Counties with population losses occurred predominately in the Midwest but also can be found scattered throughout the country.

States with the greatest increase in population density between 1990 and 1996 were in the Eastern United States: New Jersey (13.4 people/square kilometer), Delaware (11.6 people/square kilometer), Maryland (11.5 people/square kilometer), Florida (10.5 people/square kilometer), Georgia (5.8 people/square kilometer), and North Carolina (5.5 people/square kilometer). States with the greatest percentage of increase in population (1990-96) were in the West: Nevada (33.4 percent), Arizona (20.8 percent), Idaho (18.1 percent), Utah (16.1 percent), and Colorado (16.0 percent). States with the greatest projected population increases between 1990 and 2045 are in the South and West including California, Florida, and Texas (fig. 6).

The country's population currently has the following racial and ethnic distribution: white (80.6 percent), black (12.1 percent), Hispanic (8.8 percent), Asian-Pacific Islander (2.6 percent), and Native American (0.8 percent) (table 3). Race and ethnic structure of the population have distinct regional patterns. In 1990, the Northeast (particularly Vermont, Maine, and New Hampshire) had the highest percentage of total state population that was white (table 3). The South (particularly Mississippi, Louisiana, and South Carolina) had the highest percentage of total state population that was black (fig. 7). The Southwestern United States (particularly New Mexico, California, and Texas) had the highest percentage of total state population that was of Hispanic origin (fig. 8). The Pacific Coast region (especially California and Washington) had the highest percentage of total state population that was Asian-Pacific Islander (fig. 9). States with the highest percentage of total population that was Native American were New Mexico, Oklahoma, and South Dakota (fig. 10). Data on tree cover and population characteristics for all counties in the United States are presented in appendix 2.

Tree Cover and Population Characteristics in Metropolitan Areas

Metropolitan areas (MAs) include county-based metropolitan statistical areas (MSAs), consolidated metropolitan statistical areas (CMSAs), their primary metropolitan statistical area (PMSAs) components, and New England county metropolitan areas (NECMAs) (table 2). These areas incorporate major urban centers and their surrounding urban-influenced counties and represent U.S. urban forests in the broadest or metropolitan extent.

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[2] South includes Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

[3] West includes Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming

[4] Midwest includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

[5] Northeast includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

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Metropolitan areas (that is, urban counties) occupy 24.5 percent of the country and contain nearly 80 percent of the total U.S. population. Metropolitan areas tend to be concentrated in the Northeastern and Pacific Coast regions, which generally have a high percentage of forest cover (fig. 11). States with the highest proportion of their land in MAs are New Jersey, Massachusetts, and Rhode Island; states with the lowest proportion of MA land are Idaho, Nebraska, and Montana (table 4).

Metropolitan areas have grown substantially in extent during recent decades, expand -ing from 8.5 percent to 23.8 percent of the land area in the United States between 1950 and 1990 (fig. 12). This expansion (556 additional counties were designated as metropolitan) represents an increase of about 1 179 000 square kilometers, or an area about four times the size of Arizona.

One of the difficulties in interpreting information such as tree canopy cover and population density on an MA basis is that MAs are based on counties that differ in size across the country. Counties in the West are particularly large relative to counties in the East. Such differences make interstate comparisons of resources in MAs difficult. As county size increases, the physical influences of urbanization tend to decrease because the proportion of rural land increases. However, the political decisions that influence resource management at the county level are frequently dominated by urban centers in MAs. Thus, urban influences in MAs are often strong, regardless of the county size.

Metropolitan Area Tree Cover

Metropolitan areas across the Nation average 33.4 percent tree cover (table 4). Metropolitan areas contain 661 220 square kilometers of tree canopy cover, the equivalent of a dense forest area (that is, 100 percent canopy cover) nearly the size of Texas.

Percentage of tree cover in MAs tends to follow the same general pattern as overall percentage of tree cover across the United States, with the highest percentages in the Northwestern and Eastern regions of the country (fig. 12). The highest average percentages of tree cover in MAs across a state occur in Oregon, Georgia, and West Virginia; the lowest in Wyoming, New Mexico, and Nevada (table 4, fig. 11). States with the highest proportion of their total state tree cover in MAs are in the largely metropolitan and heavily forested Northeast.

Individual MSAs and PMSAs with the highest percentages of tree cover include Eugene, OR, Asheville, NC, and Medford, OR. The MSAs and PMSAs with the lowest percentages of tree cover are Lubbock, Odessa, Laredo, and Amarillo, TX (appendix 2). Within individual CMSAs, the Seattle-Tacoma-Bremerton CMSA has the highest percentage of tree cover, and the Los Angeles-Riverside-Orange County CMSA has the lowest percentage of tree cover (appendix 2).

Percentage of tree cover tends to increase as one moves from the more intensely developed urbanized core to the outer boundaries of the MA, particularly in heavily forested areas of the country (for example, Portland, OR, and Seattle). In other instances (for example, Cincinnati and Cleveland), the percentage of tree cover in urbanized areas is quite high relative to the surrounding areas (appendix 2). These results reflect the combination of intensely developed urban areas that support a substantial tree cover and the influence of agricultural land uses that often reduce tree cover in areas surrounding cities.

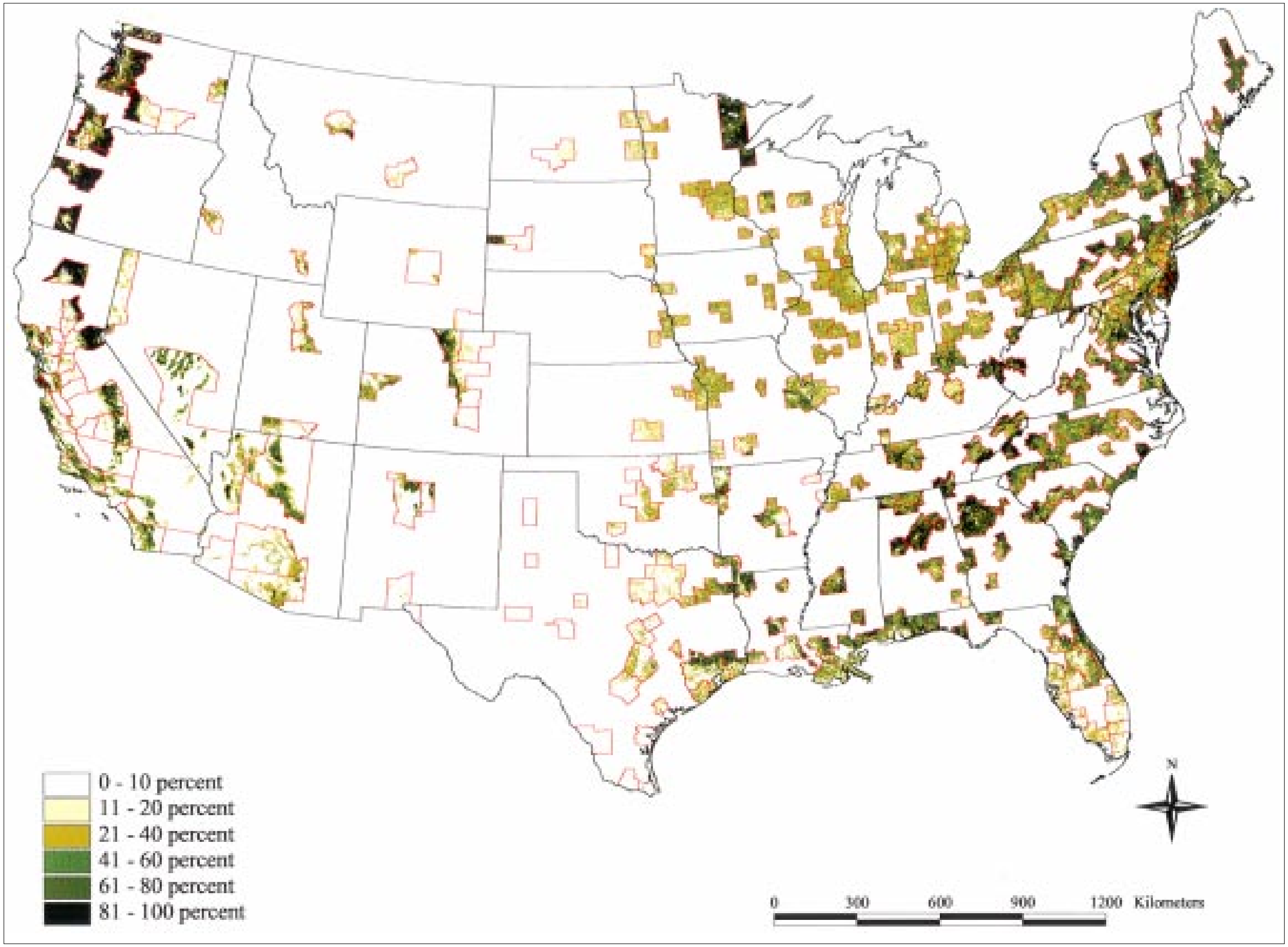

Figure 11—Spatial distribution of tree cover within metropolitan areas (MAs), based on AVHRR data (Zhu 1994).

Table 4—Area, tree cover, and tree population in metropolitan areas (MA) and urban areas (UA), by state

State	Area		Area of state[a]		Tree cover[b]		State tree cover[c]		Tree population		Trees/capita	
	MA	UA	MA	UA	MA	UA	MA	UA	MA	UA	MA	UA
	Square kilometers		*Percent*						*Thousand trees*			
Alabama	44,950	8,487	33.1	6.3	57.5	48.2	29.7	4.7	3,767,917	205,847	1,391	69
Arizona	159,133	9,218	53.9	3.1	12.9	11.4	45.5	2.4	633,609	53,950	198	9
Arkansas	23,023	3,435	16.7	2.5	30.6	25.0	12.3	1.5	910,335	43,412	821	32
California	253,807	27,348	59.9	6.4	20.6	10.9	39.2	2.2	2,134,318	148,612	74	5
Colorado	49,353	4,345	18.3	1.6	20.5	13.0	15.1	0.8	738,130	28,149	266	7
Connecticut	10,561	4,085	73.6	28.5	39.1	21.8	65.2	14.0	431,348	44,800	143	14
Delaware	3,351	566	52.0	8.8	50.9	46.3	58.2	9.0	212,596	13,257	384	27
Florida	97,442	18,407	57.2	10.8	31.1	18.4	49.5	5.5	3,459,653	169,587	288	13
Georgia	34,339	8,338	22.3	5.4	68.1	55.3	24.0	4.7	3,442,105	232,906	791	49
Idaho	7,282	966	3.4	0.4	23.7	25.6	1.9	0.3	133,053	12,494	368	18
Illinois	48,489	9,165	32.3	6.1	38.6	33.7	33.0	5.5	1,951,744	155,544	204	14
Indiana	36,324	5,000	38.5	5.3	36.5	31.2	35.7	4.2	1,480,599	78,498	374	21
Iowa	17,092	3,148	11.7	2.2	36.7	33.1	11.5	1.9	626,272	52,474	522	29
Kansas	14,819	2,575	7.0	1.2	21.5	20.5	17.4	2.9	333,535	26,677	250	17
Kentucky	17,216	3,374	16.4	3.2	42.7	33.4	12.5	1.9	839,464	56,681	472	23
Louisiana	53,818	5,374	40.1	4.0	38.2	25.3	36.0	2.4	2,507,970	68,510	794	19
Maine	13,651	2,887	14.9	3.1	64.7	47.7	14.0	2.2	1,942,124	68,550	3,924	110
Maryland	18,340	4,525	57.1	14.1	46.5	40.1	53.2	11.1	850,811	89,434	192	21
Massachusetts	23,403	6,893	85.6	25.2	45.1	25.3	88.4	14.4	1,258,989	86,829	212	17
Michigan	54,971	7,494	21.9	3.0	37.4	29.7	15.0	1.6	2,486,540	110,858	323	17
Minnesota	46,555	6,775	20.7	3.0	50.0	37.4	20.2	2.2	2,795,672	127,767	929	33
Mississippi	16,745	3,365	13.3	2.7	54.8	38.6	12.9	1.8	1,287,176	65,520	1,472	48
Missouri	31,838	5,655	17.6	3.1	36.1	30.6	15.3	2.3	1,323,812	87,148	379	21
Montana	13,885	4,365	3.6	1.1	16.9	49.4	2.4	2.2	140,484	108,550	735	251
Nebraska	6,892	1,061	3.4	0.5	29.8	21.1	8.0	0.9	164,718	11,243	209	10
Nevada	84,958	3,195	29.7	1.1	12.1	9.9	26.5	0.8	129,004	15,834	127	9
New Hampshire	5,362	1,678	22.1	6.9	58.8	49.1	17.7	4.6	453,046	41,455	660	60
New Jersey	22,590	6,916	100.0	30.6	56.6	41.4	100.0	22.3	1,596,644	143,869	207	20
New Mexico	30,528	2,316	9.7	0.7	11.9	4.8	9.0	0.3	264,298	5,682	314	4
New York	72,841	10,127	51.6	7.2	44.7	26.3	43.9	3.5	4,597,839	132,466	278	8
North Carolina	48,529	6,419	34.8	4.6	52.5	42.9	31.4	3.4	4,356,839	138,606	996	36
North Dakota	17,667	457	9.6	0.2	14.3	7.8	11.8	0.2	148,126	1,774	575	5
Ohio	55,178	9,923	47.5	8.5	44.7	38.3	45.6	7.0	3,249,536	191,113	368	22
Oklahoma	31,926	7,940	17.6	4.4	16.7	14.5	16.8	3.6	600,218	58,204	321	16

Table 4—Area, tree cover, and tree population in metropolitan areas (MA) and urban areas (UA), by state (continued)

State	Area		Area of state[a]		Tree cover[b]		State tree cover[c]		Tree population		Trees/capita	
	MA	UA	MA	UA	MA	UA	MA	UA	MA	UA	MA	UA
	Square kilometers		– – – – – – – – – – – – *Percent* – – – – – – – – – – – – –						– – *Thousand trees* – –			
Oregon	36,108	2,280	14.2	0.9	75.1	30.4	22.6	0.6	2,138,017	34,583	1,077	17
Pennsylvania	58,315	8,363	48.9	7.0	48.7	34.4	43.5	4.2	3,732,947	139,020	370	16
Rhode Island	3,189	926	79.7	23.2	38.3	8.9	88.9	6.0	129,074	4,155	141	5
South Carolina	33,670	4,380	40.6	5.3	54.4	39.8	38.5	3.6	2,986,395	86,696	1,233	44
South Dakota	10,818	617	5.4	0.3	25.1	19.2	10.6	0.5	17,682	6,007	80	15
Tennessee	33,420	7,382	30.6	6.8	53.8	43.9	28.1	5.1	2,404,114	163,783	726	49
Texas	143,184	26,573	20.6	3.8	15.8	10.5	29.4	3.6	2,755,780	140,709	195	8
Utah	21,628	2,577	9.8	1.2	19.5	14.0	11.4	1.0	209,934	18,330	157	9
Vermont	3,903	416	15.7	1.7	48.9	36.0	10.5	0.8	242,078	7,558	1,367	42
Virginia	40,759	8,869	36.8	8.0	53.3	35.3	34.4	4.9	3,647,767	156,545	764	27
Washington	52,953	5,679	28.7	3.1	50.9	33.6	28.6	2.0	2,089,982	93,272	518	23
West Virginia	10,108	1,086	16.1	1.7	65.6	42.2	13.4	0.9	890,930	22,871	1,191	33
Wisconsin	43,747	4,565	25.8	2.7	39.0	25.8	21.8	1.5	1,886,180	59,344	566	18
Wyoming	20,885	797	8.2	0.3	4.1	3.6	2.0	0.1	43,464	1,392	323	3
United States[d]	1,979,700	281,000[e]	24.5	3.5	33.4	27.1	24.5	2.8	74,425,644	3,820,491	377	17

[a] Percentage of the state's total area that is occupied by metropolitan areas (MA) and urban areas (UA).

[b] Percentage of metropolitan area (MA) or urban area (UA) covered by tree canopies.

[c] Percentage of total state tree cover within metropolitan areas (MA) and urban areas (UA).

[d] Includes the District of Columbia, but not Alaska and Hawaii.

[e] Includes 492 square kilometers of urban area (UA) that crossed state borders and could not be assigned to an individual state.

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The number of trees estimated to be within MAs of the United States is 74.4 billion. To put this figure in perspective, an estimated 319 billion live trees populate U.S. commercial timberland (USDA Forest Service 1982). States with the highest estimated number of trees in MAs are in the heavily forested East and include New York, North Carolina, and Alabama. States with lowest number of trees in MAs are in the Midwest to Western regions and include South Dakota, Wyoming, and Nevada (table 4).

Metropolitan Area Population Characteristics

The geographic expansion of MAs during recent decades was accompanied by significant population growth in these areas. The MA population grew from about 92.5 million (61.5 percent of the total population) in 1950, to a 1996 metropolitan population of 211.8 million (79.8 percent of the total population). Currently, states with the highest proportion of their population in MAs are in the Northeastern and Pacific Coast regions of the country and include New Jersey, Massachusetts, and California (table 4). States with the lowest percentage of their populations living in MAs are mainly in the West.

The most densely populated MAs are in the Northeast and along the Pacific Coast and include Jersey City and Bergen, NJ, New York City, and Orange County and Los Angeles (appendix 2). Metropolitan areas with the lowest population densities are in the Midwest and Western states and include Flagstaff and Yuma, AZ; Casper and Cheyenne, WY; and Bismark, ND. The lower population densities for MAs in the West are due, in part, to the larger size of counties in this region.

The racial and ethnic composition of MAs differs across the United States (appendix 2). The regional patterns for racial and ethnic composition exhibited among MAs are similar to the regional patterns exhibited among the states (see “National Population Characteristics,” above).

Tree Cover and Population Characteristics in Urban Areas

Urban areas include census-defined urbanized areas and incorporated or unincorporated places with at least 2,500 people (table 2). This classification includes geographic areas where populations and urban influences are most concentrated and encompasses the cities, towns, and villages comprising the area considered by many to be the urban forest.

Urban areas occupy 3.5 percent or 281 000 square kilometers of the United States. An earlier estimate of the extent of urban area, based on land use data from 1969, was 279 000 square kilometers (Grey and Deneke 1986). This previous estimate of urban area was excessive, as it included nonurban transportation lands (that is, railways and interstate highway systems). Excluding nonurban transportation land, the estimated urban area in the United States in 1969 would be adjusted to 139 000 square kilometers, or about 1.7 percent of the United States (Frey 1973). Thus, results from our assessment indicate that urban land in the United States has doubled between 1969 and the early 1990s (about 20 years).

Urban areas tend to be concentrated in the Northeastern and Pacific Coast regions. States with the highest proportion of their land in UAs are New Jersey, Connecticut, and Massachusetts (figs. 2 and 13, table 3). States with the lowest proportion of their land in UAs are North Dakota, Wyoming, and South Dakota (table 4). The Northeastern United States has the highest proportion of its land in UAs. Of the 10 most urbanized states, 9 are in the Northeast.

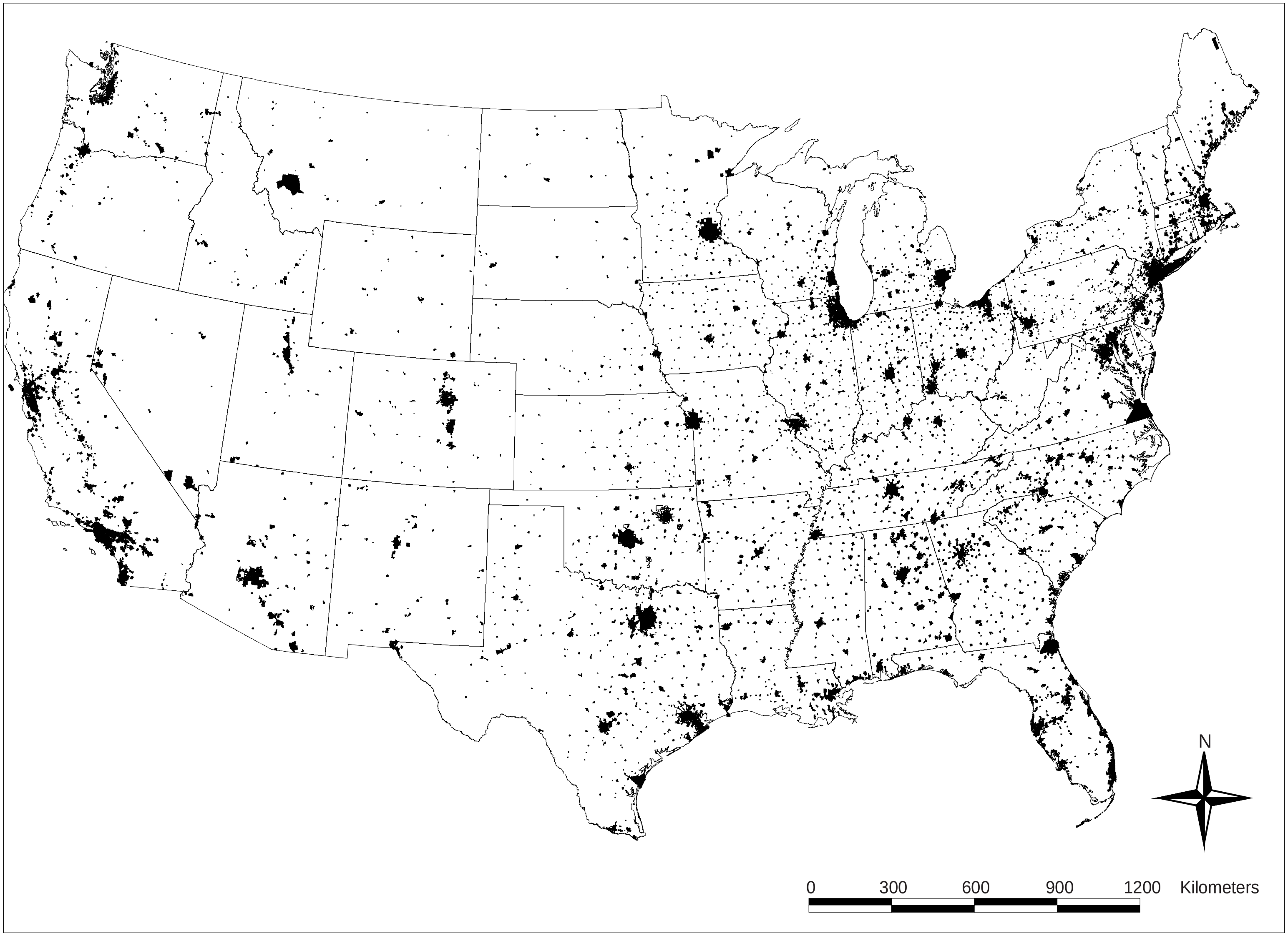

Figure 13—Location of urban places and places within urbanized areas analyzed in the conterminous United States.

Rural places (table 2), or places with a total population of less than 2,500 and located outside urbanized areas, make up 0.8 percent of the U.S. land area.[6] Though focusing on slightly different parameters of urbanization, the NRI estimate[7] of total urban and built-up land (4.5 percent) is comparable to the amount of land in urban area and rural places in the United States (4.3 percent).

Urban Area Tree Cover

Nationally, urban areas have an average tree cover of 27.1 percent (table 4, fig. 13). This percentage of tree cover is not far below the national average for all lands (32.8 percent). The highest average percentages in UAs across a state are found in Georgia, Montana,[8] and New Hampshire. States with the lowest average percentages in UAs are Wyoming, New Mexico, and North Dakota (table 4, fig. 14).

States with the highest proportion of their total tree cover occurring in UAs include New Jersey, Massachusetts, and Connecticut (table 4). Tree cover in individual urbanized areas was highest in the Eastern United States. Individual urbanized areas with the highest percentage of tree cover include Asheville, NC; Vineland-Millville, NJ; and Rome, Atlanta, and Athens, GA (appendix 2). Tree cover in all census-defined urbanized areas and places that comprise urban areas is given in appendix 2.

Three factors help to explain variation in percentage of tree cover among urban areas: ecoregion type, population density, and land use. Based on an analysis of all urban areas in the United States, urban tree cover tends to be highest in urban areas developed in forested ecoregions (34.4 percent) followed by grasslands (17.8 percent) and deserts (9.3 percent). These results are consistent with previous estimates of urban tree cover by ecoregion types (based on aerial photo interpretation of 58 U.S. cities), where tree cover averaged 31.1 percent in forest cities, 18.9 percent in grassland cities, and 9.9 percent in desert cities (Nowak and others 1996).

Percentage of tree cover in urban areas tends to decrease as population density increases in all ecoregion types (forest: $r = -0.37$; grassland: $r = -0.25$; desert: $r = -0.18$). This pattern is consistent with results from an analysis of 58 U.S. cities, which showed that the percentage of total greenspace (bare soil and vegetation cover) in cities tends to decrease with population density, regardless of ecoregion type ($r = -0.64$) (Nowak and others 1996).

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[6] These statistics do not include inhabited and uninhabited rural lands that are not recognized by the U.S. Bureau of the Census as “places” (for example, National Parks, National Forests, state and local natural resource preserves, and other rural areas).

[7] The NRI classification of urban and built-up land is based on land use and structural characteristics regardless of population. The NRI incorporates built-up areas into its urban classification and includes areas typically considered to be rural, while omitting large tracts (>10 acres) of more natural features that can be found within urban areas. The NRI estimate also excludes Federal land.

[8] The amount of urban area in Montana is high owing to the inclusion of the Anaconda-Deer Lodge CDP, which encompasses the entire area of Anaconda-Deer Lodge County.

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Click here for fig 15 color map page 31

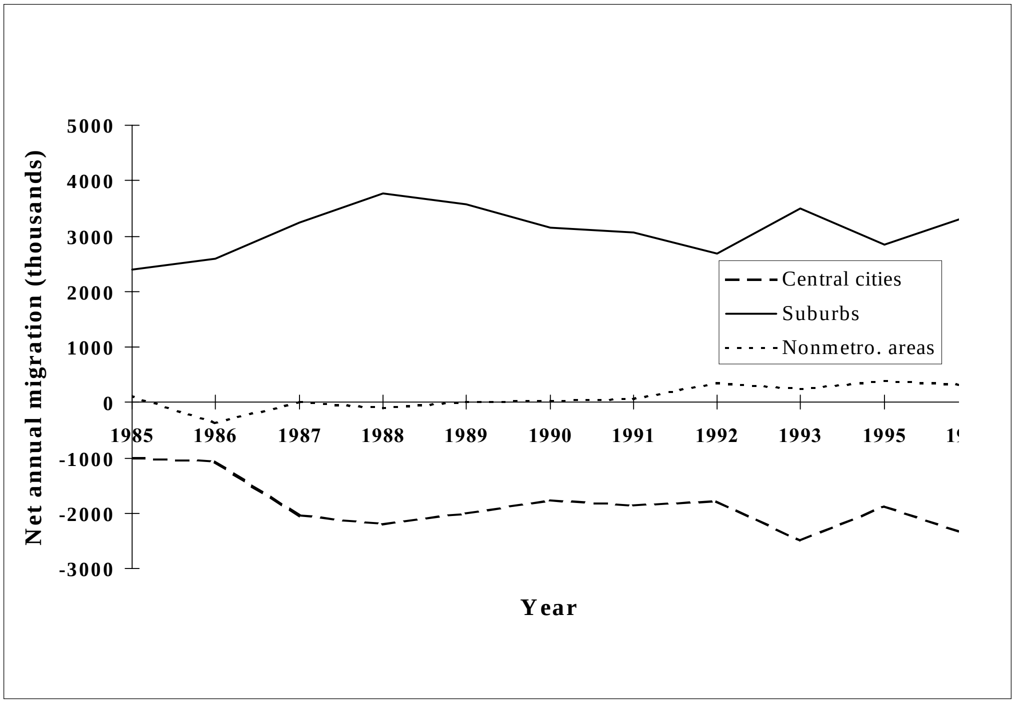

Figure 16—Net annual migration from central cities, suburban areas, and nonmetropolitan areas in the United States, 1985-96 (U.S. Department of Commerce, Bureau of the Census 1998b).

Percentage of tree cover in urban areas tends to increase with increasing city size in forest and grassland areas but decreases with city size in desert areas. This pattern is likely a reflection of the distribution of land uses in cities, which is a significant determinant of the amount of local tree cover (Nowak and others 1996). As city area increases, the amount of vacant land is likely to increase. In forest and some grassland areas, vacant lands tend to fill with trees through natural regeneration. Vacant land in desert regions generally does not support natural tree regeneration, however; increased vacant land therefore tends to decrease the overall percentage of tree cover in expanding desert cities. Although ecoregion is a major force in determining overall urban tree cover, both ecoregion and land use distribution within a city combine to be major determinants of the percentage of tree cover in urban areas (Nowak and others 1996).

The number of trees within UAs of the United States is estimated to be 3.8 billion. This estimate is much higher than an earlier estimate of 660 million urban trees, which was based on the conservative assumption that 10 nonstreet trees exist for every street tree in cities (Kielbaso 1990). With an estimated 60 million U.S. street trees in urban areas (Kielbaso 1990), results from this assessment reveal that about 62 nonstreet trees exist for every street tree in urban areas across the country. This national ratio is similar to that found in Oakland (57 nonstreet urban trees/street tree) (Nowak 1993a); but it is higher than the ratio found in Chicago (9) and Cook and DuPage Counties, IL (34) (Nowak 1994). States with the highest estimated UA tree populations include Georgia, Alabama, and Ohio (table 4, fig. 15). States with lowest UA tree populations are Wyoming, North Dakota, and Rhode Island.

Urban Area Population Characteristics

Between 1985 and 1996, central cities in metropolitan areas across the United States consistently lost population, averaging a loss of 1,863,000 people per year; suburbs gained population, averaging an increase of 3,106,000 people per year. Nonmetropolitan areas gained an average of 90,000 people per year, with most of the population increase occurring since 1989 (fig. 16).

Rural places make up 4.2 percent of the country's population. States with the highest percentage of population in rural places are in the Midwest and include North Dakota, South Dakota, and Iowa. States with the lowest percentage of rural population are in the Northeast and Pacific Coast and include Rhode Island, California, and New Jersey (table 5).

A comparison of socioeconomic characteristics between urban and rural populations indicates differences that may be associated with involvement in, support of, and preferences for natural resource management. Urban populations generally exhibit more racial and ethnic diversity and have a higher proportion of residents between the ages of 20 and 39; rural populations are roughly 90 percent white and contain a substantially higher proportion of older residents (that is, 60 years and older) (table 6). Urban populations also have a greater percentage of college-educated individuals and a higher median household income than rural populations.

Forest Land Within and Around Urban and Metropolitan Areas

The USDA Forest Service FIA group has a detailed definition of "forest land" (appendix 1), encompassing land typically considered to contain more "natural" forest stands with a minimum size of 0.4 hectare. Forest land has the potential to provide timber and a range of other goods and services; however, the ability to harvest timber, provide access for outdoor recreation, and administer other management activities may be greatly influenced by urban land owners and the proximity of these forest lands to urban areas.

States with the highest proportion of their forest land within MAs are in the Northeast and include New Jersey, Rhode Island, and Massachusetts (table 7). Pacific Coast states also may have high percentages of forest land in metropolitan areas (fig. 11), but forest land data for these states were unavailable.[9]

As areas of the United States become increasingly urban, and higher percentages of forest land become incorporated into MAs or UAs, the influence of the urban population on forest management and use practices will increase; for example, increased population density reduces the availability of timber from forest lands (Barlow and others 1998, Wear and others 1999). Residential developments around cities also can limit access to public and private lands for outdoor recreation (Ewert and others 1993).

To determine how much forest land is near urban areas and likely to experience strong urban influences, estimates were made of forest land within 80.5-, 160.9-, and 240.4-kilometer radii (50, 100, and 150 miles, respectively) around 53 major urban centers. Due to limitations of the forest land database, most of the 53 selected cities are in the Eastern United States. Some important considerations regarding the analysis of forest land in proximity to cities include the following: (1) classifications of forest land in and around cities may not be consistent across the country because of regional differences in the criteria used to exclude some urban counties from the forest land inventory; (2) many cities are in coastal areas and consequently have relatively low amounts of forest land around them; and (3) analyses of forest land around cities often overlap with those for nearby cities (that is, cities within twice the designated radius of each other).

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[9] At the time of analysis, FIA data for California, Oregon, and Washington were not available in the FIA database retrieval system.

Table 5— Area occupied and population of places under urban influence (urban places and places located within urbanized areas [urban]) and rural places (rural), by state[a]

	Total area		Proportion of state area[b]		1990 population		Proportion of 1990 population	
State	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	Square kilometers		*– – Percent – –*				*– – – Percent – – –*	
Alabama	7,642	2,763	5.6	2.0	2,368,109	231,309	58.6	5.7
Arizona	7,481	1,740	2.5	0.6	3,012,032	101,163	82.2	2.8
Arkansas	3,268	1,714	2.4	1.2	1,248,925	240,831	53.1	10.2
California	24,213	2,610	5.7	0.6	26,741,843	248,401	89.9	0.8
Colorado	3,845	823	1.4	0.3	2,576,377	150,453	78.2	4.6
Connecticut	2,338	264	16.3	1.8	1,964,024	50,381	59.7	1.5
Delaware	255	87	4.0	1.3	245,364	26,505	36.8	4.0
Florida	14,971	1,389	8.8	0.8	9,456,179	183,607	73.1	1.4
Georgia	6,199	2,074	4.0	1.3	2,996,366	281,026	46.3	4.3
Idaho	860	435	0.4	0.2	534,088	97,658	53.1	9.7
Illinois	7,197	1,725	4.8	1.2	9,195,059	553,277	80.4	4.8
Indiana	4,320	720	4.6	0.8	3,298,796	322,562	59.5	5.8
Iowa	3,016	1,750	2.1	1.2	1,667,571	460,640	60.1	16.6
Kansas	2,397	734	1.1	0.3	1,688,899	292,754	68.2	11.8
Kentucky	3,070	791	2.9	0.8	1,796,940	197,339	48.8	5.4
Louisiana	4,775	1,824	3.6	1.4	2,685,248	199,458	63.6	4.7
Maine	2,839	482	3.1	0.5	542,955	72,081	44.2	5.9
Maryland	4,022	368	12.5	1.1	3,745,248	97,157	78.3	2.0
Massachusetts	4,868	403	17.8	1.5	4,306,988	95,189	71.6	1.6
Michigan	6,279	1,316	2.5	0.5	5,925,280	351,250	63.7	3.8
Minnesota	6,689	3,475	3.0	1.5	3,069,259	389,881	70.2	8.9
Mississippi	3,119	1,232	2.5	1.0	1,190,741	185,675	46.3	7.2
Missouri	5,109	1,436	2.8	0.8	3,210,096	365,599	62.7	7.1
Montana	4,323	941	1.1	0.2	415,289	93,020	52.0	11.6
Nebraska	954	809	0.5	0.4	971,402	229,609	61.5	14.5
Nevada	3,022	2,172	1.1	0.8	1,033,762	37,825	86.0	3.1
New Hampshire	1,546	158	6.4	0.7	517,189	39,381	46.6	3.6
New Jersey	5,171	496	22.9	2.2	5,870,705	89,858	75.9	1.2
New Mexico	2,133	1,037	0.7	0.3	1,082,375	91,909	71.4	6.1
New York	8,108	1,884	5.7	1.3	14,107,944	454,788	78.4	2.5
North Carolina	5,183	1,965	3.7	1.4	3,028,130	351,480	45.7	5.3

Table 5— Area occupied and population of places under urban influence (urban places and places located within urbanized areas [urban]) and rural places (rural), by state[a] (continued)

	Total area		Proportion of state area[b]		1990 population		Proportion of 1990 population	
State	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	Square kilometers		*– – Percent – –*				*– – – Percent – – –*	
North Dakota	434	1,098	0.2	0.6	339,377	134,565	53.1	21.1
Ohio	8,305	1,136	7.2	1.0	7,330,000	443,632	67.6	4.1
Oklahoma	6,815	2,353	3.8	1.3	2,123,240	278,230	67.5	8.8
Oregon	2,131	558	0.8	0.2	1,932,947	134,217	68.0	4.7
Pennsylvania	5,630	1,776	4.7	1.5	6,650,547	572,907	56.0	4.8
Rhode Island	668	24	16.7	0.6	721,337	6,208	71.9	0.6
South Carolina	3,207	977	3.9	1.2	1,474,172	152,982	42.3	4.4
South Dakota	593	755	0.3	0.4	348,711	142,817	50.1	20.5
Tennessee	6,752	1,577	6.2	1.4	2,774,945	214,730	56.9	4.4
Texas	22,383	4,167	3.2	0.6	12,872,159	664,959	75.8	3.9
Utah	2,442	1,528	1.1	0.7	1,490,379	113,638	86.5	6.6
Vermont	367	228	1.5	0.9	158,521	55,382	28.2	9.8
Virginia	7,527	778	6.8	0.7	3,858,411	166,959	62.4	2.7
Washington	5,069	1,124	2.7	0.6	3,540,909	178,322	72.8	3.7
West Virginia	934	914	1.5	1.5	602,902	176,889	33.6	9.9
Wisconsin	4,289	2,270	2.5	1.3	3,103,474	377,793	63.4	7.7
Wyoming	735	338	0.3	0.1	294,584	47,135	64.9	10.4
United States[c]	237,669	61,218	2.9	0.8	170,716,698	10,443,431	69.1	4.2

[a] These data do not include inhabited and uninhabited areas of the United States that are not recognized as "places" by the U.S. Bureau of the Census (for example, National Parks, National Forests, state and local natural resource preserves, and other rural areas).

[b] Percentage of total state area occupied by urban places and places located within urbanized areas (urban) or rural places.

[c] Includes the District of Columbia, but not Alaska and Hawaii.

Source: U.S. Department of Commerce, Bureau of the Census 1992c.

Table 6—Comparison of socioeconomic attributes between urban and rural places in the conterminous United States

Socioeconomic attributes	Total population: Urban places[a]	Total population: Rural places[b]
	Percent	
Race and ethnicity:		
White	76.2	90.0
Black	14.6	6.2
Native American	0.6	2.0
Asian-Pacific Islander	3.5	0.3
Hispanic	11.2	3.7
Age:		
0-9 years	14.5	14.8
10-19 years	13.6	14.7
20-29 years	17.2	12.8
30-39 years	17.0	14.9
40-49 years	12.3	11.6
50-59 years	8.5	9.0
60 years and older	17.0	22.3
Education:[c]		
Grades 0-12 (no diploma)	24.0[d]	31.2[d]
High school diploma (or equiv.)	28.0[d]	36.5[d]
College educated	48.0[d]	32.3[d]
	Dollars	
Median household income	$ 31,255	$ 22,997

[a] Includes census-recognized places within urbanized areas or located outside urbanized areas and have a total population larger than 2,500.

[b] Includes census-recognized places located outside urbanized areas and have a total population of less than 2,500.

[c] Highest level of education for adults over 25 years of age.

[d] Percentage of total adults over 25 years of age.

Source: U.S. Department of Commerce, Bureau of the Census 1992c.

Table 7—Forest land within a state and in metropolitan areas (MA), by state

State	State forest land[a]	State forest land	State forest land in MA	State forest land in MA[b]
	Percent	– – – – *Square kilometers*	*– – – –*	*Percent*
Alabama	67.6	88,888	24,133	27.2
Arizona	10.0[c]	29,330[c]	13,654[c]	46.6[c]
Arkansas	56.4	76,045	9,589	12.6
California	—	—	—	—
Colorado	16.1[c d]	43,258[c d]	14,309[c d]	33.1[c d]
Connecticut	59.1	7,419	4,743	63.9
Delaware	31.1	1,576	618	39.2
Florida	46.9	65,648	30,898	47.1
Georgia	64.9	97,312	19,889	20.4
Idaho	35.0	74,934	635	0.9
Illinois	12.0	17,262	3,147	18.2
Indiana	19.3	17,965	5,421	30.2
Iowa	5.7	8,297	925	11.2
Kansas	2.6	5,500	864	15.7
Kentucky	49.3	50,720	5,617	11.1
Louisiana	49.5	55,815	16,133	28.9
Maine	89.6	71,629	10,190	14.2
Maryland	43.2	10,925	6,279	57.5
Massachusetts	62.0	12,582	11,000	87.4
Michigan	53.0	78,029	9,400	12.1
Minnesota	32.7	67,508	15,867	23.5
Mississippi	61.9	75,256	9,251	12.3
Missouri	31.7	56,651	7,287	12.9
Montana	13.9	52,344	1,219	2.3
Nebraska	1.5	2,907	246	8.5
Nevada	9.8[c]	28,003[c]	4,455[c]	15.9[c]
New Hampshire	84.8	19,703	3,750	19.0
New Jersey	39.8	7,645	7,645	100.0
New Mexico	10.1[c]	31,731[c]	3,593[c]	11.3[c]
New York	52.8	64,564	27,317	42.3
North Carolina	61.8	78,016	25,212	32.3
North Dakota	1.3	2,283	101	4.4
Ohio	30.2	32,042	12,793	39.9
Oklahoma	12.3[e]	21,925[e]	936[e]	4.3[e]
Oregon	—	—	—	—
Pennsylvania	57.3	66,532	27,371	41.1
Rhode Island	55.5	1,503	1,407	93.6
South Carolina	65.6	51,177	19,413	37.9
South Dakota	0.5[e]	1,059[e]	19[e]	1.8[e]

Table 7—Forest land within a state and in metropolitan areas (MA), by state (continued)

State	State forest land[a]	State forest land	State forest land in MA	State forest land in MA[b]
	Percent	*– – – – Square kilometers – – – –*		*Percent*
Tennessee	51.6	55,050	13,944	26.1
Texas	7.1[e]	48,334[e]	13,427[e]	27.8[e]
Utah	29.8	63,443	7,474	11.8
Vermont	74.9	17,953	1,995	11.1
Virginia	62.3	63,868	20,840	32.6
Washington	—	—	—	—
West Virginia	78.0	48,681	7,127	14.6
Wisconsin	46.0	64,765	9,025	13.9
Wyoming	5.1[c]	12,818[c]	884[c]	6.9[c]

— Data not reported for the state.

[a] Forest land is defined as “land currently growing forest trees of any size with a total stocking value of at least 16.7 (10 base 100 in the West), or lands formerly forested, currently capable of becoming forest land, and not currently developed for nonforest uses” in Forest Inventory Analysis (FIA) database (USDA Forest Service 1997a). These lands must be a minimum of 0.4 hectare in area.

[b] MAs include primary metropolitan statistical areas (PMSAs), metropolitan statistical areas (MSAs), and New England county metropolitan areas (NECMAs) for the New England states. MA components are based on the 1996 U.S. census definitions for MSA, PMSA, and NECMA (U.S. Department of Commerce, Bureau of the Census 1997).

[c] Does not include National Forest System land.

[d] Including western counties only.

[e] Including eastern counties only.

Source: USDA Forest Service 1997a.

Cities with the highest proportion of forest land within a 80.5-kilometer radius are in the Southern United States and include Lafayette and Baton Rouge, LA, and Birmingham, AL (table 8). The rankings among the 53 cities analyzed by percentage of forest land were relatively consistent, regardless of the area's radius (that is, 80.5, 160.9, or 240.4 kilometers); however, the overall percentage of land classified as forest tended to increase for most cities as the radius of analysis expanded. This pattern was most likely attributable to a higher level of displacement of forest land by urbanization nearer to the core of the city, as well as the tendency to classify land in and adjacent to cities as nonforest.

Cities in forest ecoregions have the most forest land in their immediate vicinity. These forest lands comprise a large resource that dominates the areas around some urban centers. These areas are often in immediate threat of being converted to other land uses or land covers as adjacent cities expand. Development of these surrounding forest lands for urban needs will significantly impact the regional landscape, production of timber, and availability of outdoor recreation and other forest services for the urban population. In the years ahead, the impacts of urban expansion on surrounding forest land are likely to be greatest in the Southern United States, where areas near cities are heavily forested and considerable population growth is expected to occur (Barlow and others 1998). The expansion of Atlanta into surrounding forest areas (Moll and Berish 1996) is an example of the type of change that may be experienced in other areas, particularly in the Southeast.

Urbanization and the National Forests

National Forests throughout the United States are increasingly affected by urban expansion and increased use by urban populations. Some National Forests are located partially within MAs and have relatively high population densities nearby (fig. 12). In addition, seasonal home developments, particularly in the upper Great Lakes region and the West, frequently are concentrated in areas near National Forests (fig. 17). The owners of seasonal homes, many of whom are urban residents, can have a significant influence on the management and use of National Forests and other nearby natural resources.

Due to the intense and diverse pressures on forest management in National Forests that are under a high degree of urban influence, 14 "urban National Forests" have been identified. Urban National Forests (UNFs) are National Forests generally located within 80.5 kilometers of populations greater than 1 million people and at the time of this writing included the following: Angeles (CA), Arapaho and Roosevelt (CO), Chattahoochee-Oconee (GA), Cleveland (CA), Gifford Pinchot (WA), Los Padres (CA), Mount Baker-Snoqualmie (WA), Mount Hood (OR), Pike and San Isabel (CO), San Bernardino (CA), Tonto (AZ), Uinta (UT), Wasatch-Cache (UT), and White Mountain (NH) (USDA Forest Service 1998b).

Special challenges faced by UNFs include wide-ranging and greater use; increased pressures from and interactions with adjacent owners and developments, such as increased foot traffic, concerns over landscape views, trash, fire ignition, and invasion of exotic plants and animals; a high degree of visibility to a large population; and increasingly complex planning and decisionmaking processes involving many diverse individuals, groups, and organizations. The pressures faced by UNFs are likely to be faced by many other National Forests and large public holdings across the country as urban influences spread across the United States. As urban populations continue to expand and increase, not only will their effects disperse over larger areas but the intensity of their impacts on forest resource management and use also are likely to increase.

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Table 8—Forest land by area and timberland by area and ownership within 80.5-, 160.9-, and 240.4-kilometer radii of selected cities

	Forest land[a]		Timberland[b]		Timberland ownership			
Radius and city	Percentage	Area	Percentage	Area	National Forest	Other public[c]	Forest industry	Other private[d]
	Percent	*Km^2*	*Percent*	*Km^2*	– – – – – – – – *Percent* – – – – – – – –			
80.5 kilometers (50 mi):								
Lafayette, LA	98.1	5,479	100.0	5,479	0.0	5.5	14.1	80.3
Birmingham, AL	95.8	13,445	100.0	13,445	3.0	2.8	21.0	73.2
Baton Rouge, LA	93.7	11,533	100.0	11,533	0.0	4.2	19.3	76.5
New Orleans, LA	87.5	5,436	100.0	5,436	0.0	6.1	21.2	72.8
Shreveport, LA	83.9	13,525	100.0	13,525	0.9	2.7	23.3	73.1
Charleston, WV	81.1	16,185	99.9	16,168	0.1	3.4	5.1	91.4
Portland, ME	78.4	8,712	98.2	8,552	0.0	2.9	2.6	94.5
Nashville, TN	77.7	7,419	100.0	7,419	0.0	4.4	1.8	93.8
Richmond, VA	68.4	13,335	99.7	13,299	0.0	4.5	17.7	77.8
Charleston, SC	63.5	6,899	98.8	6,817	13.7	3.0	31.3	52.0
Jackson, MS	62.9	12,509	100.0	12,509	6.5	4.0	17.2	72.2
Atlanta, GA	58.4	11,670	99.9	11,653	0.0	2.8	11.9	85.3
Greensboro, NC	57.9	11,536	99.6	11,492	0.8	1.7	4.1	93.5
Little Rock, AR	56.7	11,234	98.5	11,065	6.3	6.0	37.0	50.7
Charlotte, NC	55.2	10,813	99.6	10,765	1.0	0.8	10.1	88.1
Raleigh, NC	54.8	10,924	99.7	10,890	0.0	2.9	5.1	92.0
Norfolk, VA	51.4	4,578	97.4	4,458	0.0	7.6	20.2	72.1
Pittsburgh, PA	50.8	10,266	95.6	9,818	0.0	6.9	0.5	92.6
Buffalo, NY	43.3	5,134	97.8	5,020	0.0	6.2	1.2	92.5
Washington, DC	40.8	6,975	87.6	6,108	0.0	7.5	1.4	91.1
Louisville, KY	40.1	8,117	98.2	7,969	4.0	9.1	0.3	86.6
Houston, TX	39.3	4,313	100.0	4,313	1.9	5.2	13.1	79.8
Orlando, FL	37.7	6,542	94.3	6,166	9.4	17.4	2.2	71.0
Rochester, NY	37.4	4,695	94.4	4,431	0.0	4.4	0.0	95.6
Lexington, KY	35.7	7,211	98.6	7,109	7.5	0.6	0.4	91.5
Philadelphia, PA	35.3	6,927	94.4	6,537	0.0	20.3	0.0	79.7
Memphis, TN	34.7	5,286	99.9	5,283	2.4	11.3	3.2	83.1
New York, NY	34.1	3,674	85.1	3,127	0.0	21.2	0.0	78.8
Grand Rapids, MI	33.7	5,750	99.3	5,712	6.9	12.2	0.0	80.9
Cleveland, OH	31.5	3,805	82.3	3,132	0.0	5.3	0.0	94.7
Baltimore, MD	30.5	5,506	84.4	4,648	0.0	4.9	1.2	93.9
Cincinnati, OH	30.0	5,972	97.0	5,793	0.0	1.6	0.0	98.4
Salt Lake City, UT	29.7	4,732	48.2	2,283	53.3	5.8	0.0	40.9
Boise, ID	29.5	5,624	99.1	5,574	83.3	6.8	3.6	6.3
Green Bay, WI	28.4	3,961	99.0	3,920	2.7	6.9	2.2	88.2
St. Louis, MO	24.9	4,959	95.0	4,711	0.0	5.4	0.5	94.2

Table 8—Forest land by area and timberland by area and ownership within 80.5-, 160.9-, and 240.4-kilometer radii of selected cities (continued)

	Forest land[a]		Timberland[b]		Timberland ownership			
Radius and city	Percentage	Area	Percentage	Area	National Forest	Other public[c]	Forest industry	Other private[d]
	Percent	*Km²*	*Percent*	*Km²*	– – – – – – – – *Percent* – – – – – – – –			
Tampa, FL	24.3	3,007	91.0	2,736	0.0	33.7	0.0	66.3
Columbus, OH	20.5	4,003	96.5	3,862	0.4	3.0	3.9	92.7
Detroit, MI	19.2	2,280	92.9	2,117	0.0	7.4	0.0	92.6
Madison, WI	17.7	3,509	96.9	3,400	0.0	8.5	0.0	91.5
Indianapolis, IN	14.1	2,809	95.2	2,675	1.6	13.7	0.9	83.8
Minneapolis, MN	13.0	1,253	94.6	0	0.0	18.7	0.0	81.3
Miami, FL	13.0	2,505	0.0	2,370	0.0	100.0	0.0	0.0
Milwaukee, WI	11.7	1,386	98.7	1,367	0.0	16.7	0.0	83.3
Kansas City, KS-MO	11.0	2,112	98.4	2,078	0.0	6.9	0.5	92.6
Billings, MT	10.2	1,975	96.5	1,906	0.0	8.6	0.0	91.4
Des Moines, IA	6.9	1,403	93.7	1,315	0.0	5.4	0.0	94.6
Great Falls, MT	6.3	1,191	100.0	1,191	0.0[e]	14.8[e]	0.0[e]	85.2[e]
Chicago, IL	5.7	802	69.1	554	0.0	4.4	0.0	95.6
Rapid City, SD	3.7	440	88.7	390	0.0	18.7	0.0	81.4
Omaha, NE	3.4	672	91.7	616	0.0	5.3	1.9	92.8
Fargo, ND	3.1	678	97.3	660	1.4	7.5	0.0	91.0
Wichita, KS	1.1	218	90.9	198	0.0	4.3	0.0	95.7
160.9 kilometers (100 mi):								
Lafayette, LA	94.4	26,879	100.0	26,879	4.7	5.4	26.8	63.1
Birmingham, AL	93.7	50,935	99.8	50,827	4.1	2.7	20.8	72.4
Baton Rouge, LA	86.7	31,637	100.0	31,637	2.8	6.0	19.8	71.4
Portland, ME	84.1	37,697	98.3	37,063	7.2	3.5	11.6	77.7
New Orleans, LA	83.7	26,516	99.9	26,487	5.0	5.6	20.7	68.7
Charleston, WV	77.3	62,308	99.2	61,797	6.7	3.3	7.1	82.8
Shreveport, LA	77.0	54,604	99.9	54,532	4.6	2.6	29.8	63.0
Atlanta, GA	72.9	53,837	99.2	53,380	7.7	3.1	16.7	72.4
Nashville, TN	72.4	38,783	99.2	38,455	0.0	6.5	7.7	85.9
Jackson, MS	64.8	46,256	100.0	46,256	4.9	3.9	18.8	72.5
Charleston, SC	63.5	25,904	98.9	25,611	3.6	4.7	24.7	67.0
Charlotte, NC	62.6	49,621	98.9	49,078	3.7	3.6	9.5	83.3
Richmond, VA	61.9	42,030	97.0	40,749	1.1	3.9	15.0	80.0
Little Rock, AR	60.8	47,858	98.4	47,081	15.1	5.0	28.1	51.7
Raleigh, NC	60.7	48,501	99.8	48,415	0.4	4.2	13.6	81.8
Norfolk, VA	58.7	24,643	98.9	24,375	0.0	5.6	21.6	72.8
Greensboro, NC	58.5	46,524	99.3	46,182	2.1	3.6	5.9	88.4
Pittsburgh, PA	58.2	46,860	97.2	45,535	3.8	9.2	2.1	84.8
Buffalo, NY	54.7	20,708	97.2	20,129	7.8	7.4	7.8	76.9

Table 8—Forest land by area and timberland by area and ownership within 80.5-, 160.9-, and 240.4-kilometer radii of selected cities (continued)

Radius and city	Forest land[a] Percentage	Forest land[a] Area	Timberland[b] Percentage	Timberland[b] Area	Timberland ownership National Forest	Other public[c]	Forest industry	Other private[d]
	Percent	*Km²*	*Percent*	*Km²*	*– – – – – – – – Percent*			*– – – – – – – –*
Houston, TX	53.2	17,194	97.9	16,839	4.7	1.7	41.4	52.2
Rochester, NY	51.0	22,753	97.2	22,108	0.0	9.6	3.4	86.9
Lexington, KY	49.4	39,430	98.2	38,716	7.1	2.7	1.6	88.6
New York, NY	48.0	20,090	91.6	18,409	0.0	17.4	0.1	82.5
Washington, DC	46.1	33,058	93.6	30,926	1.8	7.4	6.2	84.5
Green Bay, WI	44.4	23,541	98.2	23,125	8.4	15.8	9.3	66.4
Baltimore, MD	40.9	29,228	93.1	27,224	0.2	11.7	3.5	84.6
Philadelphia, PA	39.4	22,729	94.1	21,391	0.0	20.3	0.6	79.0
Memphis, TN	37.0	24,623	100.0	24,613	2.9	11.1	7.6	78.4
Louisville, KY	36.3	29,121	97.4	28,367	2.4	5.6	0.6	91.4
Orlando, FL	34.7	17,923	95.0	17,033	8.0	14.6	15.4	62.0
Grand Rapids, MI	33.2	19,362	98.7	19,110	10.6	13.0	0.2	76.2
Cleveland, OH	32.8	16,390	94.0	15,403	0.0	4.3	0.2	95.5
St. Louis, MO	31.3	25,240	95.4	24,088	7.8	4.4	1.2	86.6
Columbus, OH	30.1	24,300	97.3	23,634	2.5	4.2	3.3	90.0
Boise, ID	29.4	15,955	92.4	14,735	83.6	6.2	4.8	5.4
Tampa, FL	28.9	11,991	92.8	11,123	7.4	19.0	7.0	66.7
Cincinnati, OH	28.0	22,639	96.8	21,910	3.3	4.8	2.8	89.1
Salt Lake City, UT	26.3	19,243	45.1	8,684	65.6	5.5	0.0	28.9
Miami, FL	22.3	5,597	21.9	1,223	0.0	7.2	0.0	92.9
Madison, WI	20.6	15,317	97.8	14,980	0.0	12.4	1.4	86.2
Minneapolis, MN	20.2	15,786	96.8	15,276	0.0	20.3	0.5	79.2
Indianapolis, IN	18.8	14,999	96.3	14,443	2.2	7.9	0.3	89.5
Detroit, MI	15.7	7,836	96.5	7,563	0.0	8.1	0.0	91.9
Milwaukee, WI	14.0	6,809	94.9	6,463	2.9	10.3	0.3	86.5
Great Falls, MT	12.3	8,320	73.6	6,120	25.7[e]	16.9[e]	3.4[e]	53.9[e]
Kansas City, KS-MO	11.2	8,954	97.7	8,749	0.0	6.3	0.8	92.9
Fargo, ND	9.8	7,507	96.1	7,216	0.1	28.8	2.8	68.3
Billings, MT	9.4	6,482	94.8	6,148	0.0	14.8	0.0	85.2
Chicago, IL	7.8	4,871	93.0	4,530	0.0	7.1	0.0	92.9
Rapid City, SD	6.8	3,671	78.2	2,871	2.8	14.6	0.4	82.1
Des Moines, IA	6.0	4,850	95.8	4,647	0.0	6.3	0.0	93.7
Omaha, NE	2.9	2,272	91.1	2,068	0.0	2.5	0.8	96.8
Wichita, KS	2.5	1,565	71.5	1,119	0.0	4.0	3.9	92.0
240.4 kilometers (150 mi):								
Lafayette, LA	87.1	63,561	99.5	63,214	5.8	4.4	36.2	53.7
Portland, ME	85.5	75,597	97.8	73,942	5.1	5.0	20.6	69.3
Baton Rouge, LA	85.0	68,050	100.0	68,022	6.5	5.4	27.0	61.1

Table 8—Forest land by area and timberland by area and ownership within 80.5-, 160.9-, and 240.4-kilometer radii of selected cities (continued)

Radius and city	Forest land[a]		Timberland[b]		Timberland ownership			
	Percentage	Area	Percentage	Area	National Forest	Other public[c]	Forest industry	Other private[d]
	Percent	*Km²*	*Percent*	*Km²*	*Percent*			
Birmingham, AL	84.8	116,511	99.9	116,375	2.3	3.1	21.5	73.1
New Orleans, LA	83.5	57,154	99.9	57,125	5.2	4.2	21.7	69.0
Shreveport, LA	77.1	110,281	99.4	109,594	5.3	3.5	39.8	51.5
Atlanta, GA	75.9	116,571	98.9	115,327	6.9	3.6	16.5	73.0
Jackson, MS	70.8	109,632	100.0	109,600	4.3	4.8	26.3	64.7
Charleston, WV	66.1	118,735	98.7	117,169	10.0	3.1	4.7	82.2
Nashville, TN	66.0	85,142	99.1	84,342	3.8	6.4	7.5	82.3
Charleston, SC	65.5	61,771	99.4	61,385	2.2	5.7	25.3	66.8
Charlotte, NC	64.4	112,518	98.7	111,034	6.2	3.9	10.5	79.3
Greensboro, NC	64.2	114,886	99.2	113,985	6.4	3.2	10.6	79.8
Houston, TX	62.0	35,431	98.5	34,884	5.9	1.4	44.0	48.8
Raleigh, NC	61.6	101,252	99.2	100,431	2.2	4.0	16.0	77.9
Rochester, NY	60.9	58,767	95.4	56,093	3.4	16.1	5.6	74.9
Pittsburgh, PA	60.0	99,615	95.3	94,937	6.0	11.0	4.5	78.5
Buffalo, NY	59.0	49,651	94.9	47,139	4.1	15.1	5.0	75.8
Richmond, VA	58.1	85,692	96.9	83,053	7.0	4.0	11.5	77.4
Norfolk, VA	57.7	55,364	98.8	54,719	0.5	5.0	17.7	76.9
Little Rock, AR	56.9	96,924	97.9	94,852	11.2	5.5	23.7	59.6
Washington, DC	53.6	80,900	94.8	76,718	4.7	10.9	6.6	77.7
Green Bay, WI	52.1	68,457	97.9	67,030	13.8	19.1	8.3	58.8
Lexington, KY	51.5	88,974	98.4	87,558	4.8	4.8	2.5	87.9
Baltimore, MD	51.4	75,789	94.2	71,404	2.0	14.5	3.9	79.6
New York, NY	50.0	42,680	94.5	40,351	0.0	14.4	0.8	84.7
Memphis, TN	48.4	75,810	99.3	75,267	4.1	6.9	12.8	76.2
Philadelphia, PA	47.1	54,280	92.4	50,153	0.0	16.8	2.0	81.2
Louisville, KY	37.6	65,360	97.8	63,946	5.5	4.7	1.8	88.0
Orlando, FL	37.4	31,417	93.9	29,499	6.5	11.2	26.1	56.2
Columbus, OH	36.6	62,913	97.5	61,340	2.1	3.4	2.9	91.7
Tampa, FL	36.0	28,247	92.2	26,040	5.2	12.2	23.0	59.6
Cleveland, OH	35.1	44,910	95.8	43,016	4.8	4.9	1.6	88.6
Cincinnati, OH	34.4	62,285	97.8	60,934	4.9	4.9	2.0	88.2
Boise, ID	29.1	28,397	89.3	25,345	86.4	6.2	3.2	4.2
St. Louis, MO	29.0	52,148	95.3	49,715	10.6	4.9	2.2	82.3
Grand Rapids, MI	28.2	38,287	97.2	37,219	9.2	19.4	0.2	71.2
Minneapolis, MN	26.8	47,309	97.1	45,922	4.9	27.3	4.6	63.3

Table 8—Forest land by area and timberland by area and ownership within 80.5-, 160.9-, and 240.4-kilometer radii of selected cities(continued)

	Forest land[a]		Timberland[b]		Timberland ownership			
Radius and city	Percentage	Area	Percentage	Area	National Forest	Other public[c]	Forest industry	Other private[d]
	Percent	*Km²*	*Percent*	*Km²*	– – – – – – – – *Percent*	– – – – – – – –		
Salt Lake City, UT	25.0	40,173	40.0	16,073	65.9	12.0	0.0	22.1
Milwaukee, WI	24.0	33,230	97.4	32,363	6.8	10.7	1.3	81.2
Detroit, MI	22.7	27,068	96.2	26,037	1.6	10.8	0.0	87.6
Madison, WI	21.0	31,707	97.6	30,941	0.3	13.3	1.8	84.6
Miami, FL	18.9	7,849	38.9	3,052	0.0	11.1	0.0	88.8
Indianapolis, IN	17.9	32,225	96.9	31,232	2.2	6.3	0.3	91.3
Great Falls, MT	16.8	22,862	83.0	18,983	29.4[e]	16.2[e]	12.2[e]	42.1[e]
Fargo, ND	13.6	23,428	93.8	21,974	8.6	37.1	2.5	51.7
Kansas City, KS-MO	12.4	22,276	95.0	21,156	0.2	5.0	0.7	94.1
Chicago, IL	11.2	17,003	95.5	16,245	1.4	7.9	0.1	90.5
Billings, MT	8.7	12,590	91.6	11,530	0.0	20.3	4.8	74.9
Des Moines, IA	6.5	11,689	96.0	11,223	0.0	6.3	0.1	93.6
Omaha, NE	3.8	5,802	91.5	4,453	0.0	3.5	0.8	95.7
Rapid City, SD	3.8	6,872	76.7	6,285	2.8	15.3	1.3	80.7
Wichita, KS	3.3	4,141	86.1	3,566	0.0	4.2	4.0	91.9

[a] Forest land is “land currently growing forest trees of any size with a total stocking value of at least 16.7 (10 base 100 in the West), or lands formerly forested, currently capable of becoming forest land, not currently developed for nonforest use.” These lands must be a minimum of 0.4 hectare in area. (USDA Forest Service 1997a).

[b] Timberland is forest land that is producing, or capable of producing, in excess of 1.4 cubic meters per hectare per year of industrial roundwood products, and is not withdrawn from timber utilization by statute or administrative regulation.

[c] Includes Bureau of Land Management land, miscellaneous Federal land, state-administered land, and county and municipal land.

[d] Includes farmer- and rancher-owned land, private corporate land, private individual land, and tribal trust land.

[e] Includes reserved timberland (not displayed in table): Timberland that has statutory or administrative restrictions prohibiting the harvest of trees (USDA Forest Service 1997a).

Source: USDA Forest Service 1997a.

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Review

Metropolitan areas represent the broadest extent of urbanization, including 24.5 percent of the U.S. area and 80 percent of the population. With an average tree cover of 33.4 percent, metropolitan areas collectively support nearly one-quarter of the Nation's total tree canopy cover—some 74.4 billion trees. In narrowing the focus to cities, towns, and villages, forest resources in urban areas continue to comprise a substantial portion of the Nation's resource base. Covering 3.5 percent of the total area and housing more than 75 percent of the total population, urban areas account for 2.8 percent of the total tree canopy cover in the country—about 3.8 billion trees. The average percentage of tree canopy cover for both metropolitan areas (33.4 percent) and urban areas (27.1 percent) is close to that for all U.S. land (32.8 percent), thereby demonstrating that urban areas and urban influence can coexist with a significant tree canopy.

Between 1950 and 1990, metropolitan areas nearly tripled in size; urban areas doubled in size between the late 1960s and early 1990s. As urban development continues to expand over the landscape, the relation among urban growth, urban influence, and natural resource systems will become increasingly important. Many cities, particularly in the Southeast, are surrounded by forest land. The expansion of these cities likely will have a significant impact on the extent, use, and management of forest resources. As urbanization spreads into less developed rural areas, a growing percentage of the Nation's natural resources will become part of urban forest ecosystems, and increasing amounts of forest outside these systems also will be subject to urban influence.

The expansion of urban and metropolitan areas has particularly important implications for the use and management of public holdings, including National Forests, National Parks, and state and locally administered natural resources. As urban residents frequently travel to exurban areas for outdoor recreation, the demands placed on forest ecosystems in close proximity to growing urban centers pose difficult challenges to natural resource managers. Heightened resource use, increased mobility or ignition of potential hazards (for example, insects and disease, fire, invasive species), conflicts regarding recreational opportunities, and seasonal and permanent home development can greatly complicate the issues that must be addressed in protecting the health and sustainability of these valuable areas.

Chapter 3: The Urban Forest Resource at the Local Level

Introduction

The previous chapter outlined the extent of tree canopy at the urban, metropolitan, and national levels. Urban forests are far more than tree canopy, however; their structure includes several other resources that differ substantially across urban areas. Although characterized by the presence of trees, urban forests also contain ground covers (for example, grasses, shrubs, cement, and tar), buildings and structures, other urban infrastructure (for example, power lines and sewers), people, and wildlife. These elements combine to create diverse forest environments throughout the urban system. The environments range from individual trees on residential or institutional properties to dense forest stands in parks and preserves. The overall urban forest landscape is a mosaic of these different forest environments and sometimes is termed the “green infrastructure” of an urban area. Recognition of the complexity and variability of the green infrastructure at the local level is critical for developing effective policies and programs for urban forestry.

Data on urban forest ecosystem complexity and variability at the local scale unfortunately are limited. National and regional statistics on important attributes of the urban forest, such as variability in species composition, tree health, and ground cover across the urban ecosystem, are not yet available. This type of information has been compiled from comprehensive urban forest case studies of a few selected cities. Subsequent discussions of the distribution, variation, complexity, and interactions among components of urban forests over time and space are largely drawn from these studies.

This chapter draws from the findings of comprehensive urban forest studies in Chicago (McPherson and others 1993, Nowak 1994) and Oakland, CA (Nowak 1991, 1993a) to illustrate the diversity and connectedness of urban forests at the local level. Less intensive information from some other cities around the United States (Nowak and others 1996) supplements the discussion. The chapter begins with a review of the factors shaping forest structure by using data and observations from the literature to show how resource components differ across the urban system. The discussion continues with a look at the connections among trees, people, wildlife, structures, utilities, and roads and their interactions to influence the quality of the urban environment. The chapter concludes by exploring the potential effects of urban expansion on the structure and function of forest resources.

The Chicago and Oakland Studies

Every urban area is unique, but resource patterns and factors influencing those patterns found in the Chicago and Oakland areas are likely similar to what might be found in other cities around the country.

In the Chicago area, comprehensive urban forest data are available for three major geographic areas: the city of Chicago, suburban Cook County (Cook County exclusive of Chicago), and DuPage County. These two counties, which are in the grassland ecotype, comprise the central portion of the Chicago primary metropolitan statistical area (PMSA) and have the lowest percentage of tree cover of the nine counties included in this metropolitan area (appendix 3). The city itself is the most densely populated of the three areas, with 4,730 people per square kilometer (1990), followed by 1,248 people per square kilometer in suburban Cook County, and 902 people per square kilometer in DuPage County (appendix 2). The area contains nearly 51 million trees, whose crowns cover roughly one-fifth of the landscape (table 9) (Nowak 1994).

The city of Oakland is the central place of the Oakland PMSA, which includes Alameda and Contra Costa Counties. Oakland also exists within a grassland ecotype, contains 372,242 people (1990), and has a population density of 2,564 people per square kilometer (appendix 2). Tree canopy cover in Oakland is 21 percent with about 1.6 million trees (Nowak 1991, 1993a).

Vegetation data from Chicago and Oakland demonstrate the complexity and spatial variability of the urban forest resource. Variability is a function of the distribution of land uses, species composition, ground cover types, tree canopy cover, characteristics of the street tree population, available growing space, and tree age, size, and condition.

Factors Influencing Spatial Variability in Urban Forest Resources

Several natural and human factors combine to shape the extent and character of forests across the urban landscape. Of particular importance are the surrounding natural environment (ecotype), land use, intensity of urban development, duration of the land use, and resource management. The development of policies and programs to enhance management of highly variable and complex urban forest resources must recognize the influence of these important factors on current and potential forest structure and function. By understanding the connections among land use, population characteristics, management practices, ground covers, and vegetation patterns, managers can tailor their efforts to meet the needs of the people in a particular region, land use, or neighborhood. Knowledge of the key determinants of urban forest structure is also essential for designing comprehensive management plans and determining the appropriate allocation of management efforts across the urban landscape.

Surrounding Natural Environment (Ecotype)

A primary determinant of urban tree cover and species composition is an area's natural capacity to sustain vegetation. This capacity depends on several environmental conditions, including climate (temperature, precipitation, wind, and solar radiation), geographic location (altitude and aspect), and soil-water characteristics (chemical properties and water retention). These environmental conditions help determine the potential natural vegetation (PNV) type found in an area (for example, desert, grassland, or forest). By setting the environmental context for natural regeneration and the development of planted vegetation, PNV type is an important influence on overall tree canopy cover in a city. Results from this assessment indicate that cities in forest ecotypes have significantly more tree cover (34 percent) than cities in grasslands (18 percent) or deserts (9 percent).

Table 9—Land cover, available growing space (AGS), and canopied greenspace (CG), by geographic area, in the 2-county Chicago study area

Geographic area	Land area	Land cover[a] Tree	Grass	Bldg.	Paved	Water	AGS[b]	CG[c]
	Km²	*Percent*						
Chicago	589	11.1	26.9	27.4	32.4	2.2	38.0	29.2
Suburban Cook Co.	1,861	22.5	44.7	12.6	18.2	1.9	67.2	33.5
DuPage Co.	866	18.6	56.0	9.4	13.9	2.1	74.6	24.9
All	3,316	19.4	44.4	14.5	19.7	2.0	63.8	30.4

[a] Land cover from sampling of aerial photographs.

[b] Available growing space = percentage of ground area occupied by pervious surfaces (bare soils and vegetation).

[c] Canopied greenspace = percentage of available growing space filled with trees (that is, the ratio of trees to bare soils and all vegetation).

Source: McPherson and others 1993.

The surrounding environment also may influence the management of urban trees and forests. The motivation for planting urban trees, for example, may be related to the climate of a region; trees may be planted to provide shade in hot climates, to reduce runoff in areas with high precipitation, or to block winter winds in northern regions. Further, decisions to restrict tree planting also may be a function of the regional environment; for example, a limited water supply may discourage tree planting efforts in arid regions.

Ecotype has a particularly strong influence on the structure of the urban forest on lands where manipulation of the vegetation is minimal. Such lands may include forest and wildlife preserves, natural areas, and vacant lands. Even in areas aggressively managed, the natural environment sets important ecological limits on what can be accomplished through management activities.

With variations in temperature, altitude, precipitation, solar radiation, and other factors influencing PNV, different forest species compositions can be expected across and among urban areas. The species composition of the urban forests in Chicago and Oakland are very different (appendix 3). Each city includes species native to the area plus exotic (introduced) species. The most common species in each of the two cities is not native to that region, or even to the United States.

The two-county Chicago area (Cook and DuPage Counties) contains a wide range of tree species, with the most common species (in number of trees) being buckthorn (*Rhamnus* spp.), green and white ash (*Fraxinus* spp.), *Prunus* spp., boxelder (*Acer negundo* L.), and American elm (*Ulmus americana* L.). Trees that dominate the landscape in terms of leaf surface area are silver maple (*A. saccharinum* L.), green and white ash, white oak (*Quercus alba* L.), American elm, and boxelder (Nowak 1994). Oakland's urban forest is comprised largely of bluegum (*Eucalyptus globulus* Labill.), Monterey pine (*Pinus radiata* D. Don), coast live oak (*Q. agrifolia* Née), and California-laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.), which account for nearly half of the tree canopy and total number of trees in the city (Nowak 1991, 1993a).

Land Use

The designated function of the land inherently defines a number of site characteristics and environmental conditions that influence tree canopy cover and urban forest structure. These site characteristics include intensity of use of open space, available growing space, building and infrastructure density, and management intensity. With the establishment, growth, and decline of urban trees heavily dependent on these factors, land use can be an important determinant of the extent, composition, and condition of forest resources in an area. Different combinations of land uses across urban areas provide a wide range of settings for growth and development of forest resources, resulting in a variable matrix of vegetation types across an entire urban system.

On average, U.S. cities typically are dominated by residential land (40.6 percent) followed by vacant and wildland (23.7 percent), commercial and industrial areas (12.7 percent), "other" land uses (that is, agriculture, orchards, transportation, and miscellaneous) (11.7 percent), institutional (6.0 percent), and parks (5.3 percent) (Nowak and others 1996).

The juxtaposition of land use and ecotypes strongly influences regional patterns of urban forest resources (Nowak and others 1996). Tree cover analyses of 37 U.S. cities in three different ecotypes show that in the forest ecotype, the land uses with the highest percentages of tree cover are parks (47.6 percent) and vacant and wild lands (44.5 percent). The lowest percentage of tree cover in the forest ecotype is found in commercial and industrial lands (7.2 percent). In the grassland ecotype, land uses with the highest and lowest percentages of tree cover are park (27.4 percent) and commercial and industrial (4.8 percent), respectively. The land use with the highest percentage of tree cover in the desert ecotype is residential (single family and multifamily) (17.2 percent); the lowest percentage of tree cover is found in vacant and wild land areas (0.8 percent). The low tree cover for the latter is most likely the result of a lack of natural regeneration or tree planting in these areas, which indicates an absence of management activities and limited availability of water. The higher percentage of tree cover in desert residential areas as compared to other land uses is likely a result of tree planting and irrigation efforts in these neighborhoods.

Variation in urban forest structure by land use also is apparent in Chicago and Oakland. In Oakland, land uses with the highest percentages of tree cover are vacant and wild lands, followed by residential (single family and multifamily), institutional, transportation, and commercial and industrial (table 10). Tree cover by land use in the Chicago area reveals a pattern similar to that in Oakland. Of all the land uses in the two-county Chicago area, institutional (vegetation) (that is, institutional lands dominated by vegetation; for example, cemeteries and golf courses), vacant, and residential (single family and multifamily) lands support the highest percentages of tree cover (table 11).

Other aspects of forest structure, including available growing space (AGS), canopied greenspace (that is, percentage of AGS covered by tree canopies), ground cover, and street tree populations, also differ by land use. Across 37 cities nationwide, land uses with the highest percentages of AGS are vacant and wildlands, parks, "other" land uses (agriculture, orchards, transportation, and miscellaneous), institutional, residential (single family and multifamily), and commercial and industrial (Nowak and others 1996). Residential areas tend to have the highest percentage of their AGS covered by tree canopy (table 12); "other" land uses have the lowest canopied greenspace. In the Chicago study area, the land uses with the highest percentages of AGS are agriculture, vacant, and institutional (vegetation); those land uses having the lowest amount of AGS are multiresidential, and commercial and industrial (appendix 3).

Table 10—Land area, tree density, tree cover, and total number of trees, by land use, Oakland, 1989

Land use	Land area	Tree density	Tree cover	No. of trees
	Km^2	*Trees/km^2*	*Percent*	
Commercial and industrial	15.4	1,013	2.2	15,600
Institutional[a]	13.4	11,254	18.3	150,800
Residential[b]	57.9	9,698	21.2	561,500
Transportation[c]	19.3	3,342	3.8	64,500
Vacant and wildland	26.3	29,202	45.9	768,000
Street trees[d]	1,000[e]	27.3[f]	.4	27,300
City of Oakland	132.4	11,992	21.0	1,587,700

[a] Including parks, schools, golf courses, and cemeteries.

[b] Single family and multifamily.

[c] Including airports, shipyards, and freeways.

[d] Between sidewalk and curb of street.

[e] Linear kilometers of planted streets.

[f] Trees per linear kilometer of planted street.

Source: Nowak 1993a.

Table 11—Tree cover by land use and geographic area for the 2-county Chicago area

Land use	Tree cover			
	Chicago	Suburban Cook Co.	DuPage Co.	All
	Percent			
Institutional (vegetation)[a]	32.5	50.0	36.8	45.6
Vacant	19.6	39.2	31.7	35.3
Residential[b]	15.0	24.4	25.3	22.9
Multiresidential[c]	6.6	8.9	10.2	8.1
Institutional (building)[d]	7.1	6.4	9.9	7.3
Agriculture	0	4.1	2.4	3.4
Commercial and industrial	2.6	2.9	1.6	2.6
Transportation	2.2	1.3	.8	1.6
All land	11.0	22.5	18.6	19.4

[a] Institutional land dominated by vegetation (parks, cemeteries, golf courses).

[b] 1- to 3-family residential units.

[c] Buildings with 4 or more apartment units.

[d] Institutional land dominated by buildings (schools, hospitals).

Sources: McPherson and others 1993, Nowak 1994.

Table 12—Mean canopied greenspace,[a] by land use, and standard error (SE) for U.S. cities in different potential natural vegetation (PNV) types[b c]

Land use	*Forest PNV* Mean	SE	*Grassland PNV* Mean	SE	*Desert PNV* Mean	SE
Residential[d]	53.6	3.3	42.6	2.1	33.4	6.1
Park	50.9	6.1	33.7	2.5	12.6	4.0
Vacant and wildland	46.6	7.7	11.4	2.6	0.8	2.0
Institutional	33.5	3.3	16.4	1.9	12.3	3.3
Commercial and industrial	24.8	3.3	25.8	3.7	18.4	2.4
Other[e]	12.9	2.2	9.1	2.1	4.6	1.7

[a] Canopied greenspace = percentage of available growing space filled with trees (that is, the ratio of trees to bare soils and total vegetation).
[b] Küchler 1969.
[c] Total *n* = 37 (forest *n* = 12; grassland *n* = 18; desert *n* = 7).
[d] Single family and multifamily.
[e] Includes agriculture, orchards, transportation (freeways, airports, shipyards), and miscellaneous.
Source: Nowak and others 1996.

Ground cover in the Chicago area differs substantially among various land use types (appendix 3). In the two-county study area, 59.7 percent of the ground surface is covered by vegetation or soil, 20.7 percent by paved surfaces, and 13.3 percent by buildings. The most common ground covers in the study area are maintained grass (29.3 percent), tar (14.3 percent), and herbaceous (12.9 percent). Impervious ground surfaces (for example, buildings and structures, cement, and tar) dominate commercial and industrial (69 percent), multiresidential (63.2 percent), and transportation (60.3 percent) areas.

The extent to which street tree populations contribute to the total tree cover of an area also differs among land uses. Although street trees constitute a relatively small portion of the total number of trees in the Chicago area, they comprise a significant portion of the total number of trees in commercial and industrial, transportation, and residential areas (appendix 3). The importance of street trees to the urban landscape is most significant in the residential (1- to 3-family dwellings) areas of Chicago, where street trees comprise 27.9 percent of total trees and 43.7 percent of total leaf surface area in that land use. In Cook and DuPage Counties, street trees in commercial and industrial and residential (1- to 3- family dwellings) sectors account for an appreciable portion of the total leaf surface area of each land use (25.8 percent and 18.0 percent, respectively) (appendix 3). Street trees tend to increase in overall importance within a land use as the use becomes more intensely developed and available planting space decreases.

Regardless of which land use supports the most vegetation, all land uses contribute important resources to the forest structure across an urban area. In sustaining the total greenspace in an urban area, each land use and location within the urban area supports an essential component of the urban forest ecosystem. The distribution of trees and other urban forest resources across multiple land uses and varying degrees of urbanization create a complex, dynamic urban forest. The consideration of vegetation and other resources on all land uses is crucial for effective management of the urban forest.

Intensity of Urbanization

As an urban area becomes more intensely developed, the amount of available growing space decreases, residential lot size is reduced, the amount of impervious ground cover increases, and tree canopy cover decreases. Intensity of urbanization generally decreases as one moves from the inner city toward rural areas, though patches of intensely urbanized or more natural areas exist throughout the urban to rural continuum. The variation in opportunities for growth of trees and other plants among locations with different degrees of urbanization contributes to the substantial differences in the structure of vegetation across land uses and the entire urban landscape. Changes in the intensity of urban development are partly responsible for an urban to rural gradient in forest structure.

The Chicago study revealed important variations in the factors and components of urban forest structure by the intensity of urbanization, including land use distribution, tree cover, ground cover, available growing space, and street tree populations. For example, the proportion of land devoted to transportation, commercial and industrial, and multiresidential (> 3 family units per dwelling) land uses decreases as one moves from the city of Chicago to suburban Cook and DuPage Counties (table 13). Conversely, the proportion of institutional (vegetation), agriculture, and vacant lands increases from inner city Chicago to its suburban areas. Variation in the distribution of land uses creates different environmental conditions, management goals, opportunities for tree establishment and growth, and vegetation patterns across the Chicago area.

These differences are illustrated with variations in tree cover across the two-county Chicago area. Overall percentage of tree cover increases from 11.0 percent in the city of Chicago to 22.5 percent in suburban Cook County (table 11). This increase seems to be due, in part, to a decrease in the intensity of urbanization from inner city Chicago to its surrounding suburban areas. The rise in percentage of tree cover also may be a function of additional opportunities for the natural regeneration of trees on the increasing proportion of institutional (vegetation) and vacant lands in areas outside Chicago (table 13). Tree canopy cover decreases from 22.5 percent to 18.6 percent as one continues from suburban Cook County to DuPage County (table 11). This trend can be explained partially by an increase in agriculture land use and a decrease in the amount of institutional (vegetation) land, such as parks, cemeteries, and forest preserves from suburban Cook to DuPage County (table 13). The reduced tree canopy cover in DuPage County also may be due to small trees associated with relatively new developments on previously cleared agricultural land. In these and many other instances, land use and degree of urbanization combine to influence the structure and function of the urban forest across the landscape.

The Chicago study also revealed variation in available growing space and the distribution of ground covers across the three geographic areas. Available growing space increases from 38 percent in Chicago to 67.2 percent in suburban Cook County and 74.7 percent in DuPage County (appendix 3). The overall distribution of ground cover types across all land uses also changes as one moves from the highly urbanized inner city toward the less intensely developed suburban areas. An increase in herbaceous, grass (maintained and unmaintained), and shrub cover occurs from inner city Chicago to suburban Cook and DuPage Counties (appendix 3). The proportion of ground covered by rock, tar, cement, buildings, and other impervious structures and covers decreases from Chicago to DuPage County. This variability in ground cover distribution across the two-county Chicago area reflects the influence of the intensity of urbanization and different combinations of land use designations (table 13) on urban forest structure.

Table 13—Distribution of land uses by geographic area for the 2-county Chicago area

Land use	Portion of total geographic area			
	Chicago	Suburban Cook Co.	DuPage Co.	All
	Percent			
Agriculture	0.1	12.6	20.9	12.5
Commercial and industrial	25.3	14.2	9.7	15.1
Institutional (building)[a]	4.7	3.8	3.2	3.8
Institutional (vegetation)[b]	8.4	17.8	10.4	14.2
Multiresidential[c]	7.7	2.1	2.4	3.2
Residential[d]	40.1	37.9	41.1	39.1
Transportation	10.9	4.0	2.7	4.9
Vacant	2.7	7.6	9.6	7.2
All land	100.0	100.0	100.0	100.0

[a] Institutional land dominated by buildings (schools, hospitals).

[b] Institutional land dominated by vegetation (parks, cemeteries, golf courses).

[c] Buildings with 4 or more apartment units.

[d] 1- to 3-family residential units.

Source: McPherson and others 1993.

Duration of Land Use and Site History

By influencing the maturity, size, and condition of forest resources, the length of time that an area supports a particular land use can play an important role in determining the urban forest structure (Sanders 1984). Land use changes often bring significant alterations to the existing vegetation as well as opportunities to establish new vegetation through planting or natural regeneration. The development of new residential neighborhoods, for example, often involves removal of vegetation, tree planting activities, and efforts to protect and maintain remaining vegetation. With continuation of residential land use over time, tree canopy cover is likely to increase. Older residential neighborhoods therefore are more likely to have established, mature tree canopies and more tree cover than newly developed residential areas. The duration of a specific land use also can influence the intensity of the associated environmental impacts on urban forests.

Because several other factors influence the size, distribution, and condition of forest resources (for example, maintenance efforts, storms, insect and disease outbreaks), broad generalizations cannot be made on the relation between forest structure and the age of an area or the duration of a land use. Observations from the Chicago study indicate, however, that forest structure may be related to the history of the geographic area; for example, because the inner city often has older, more established land use sectors than suburban areas have, one might expect a higher proportion of large, mature trees in Chicago than in suburban Cook or DuPage Counties. Results show that the relative percentage of large trees within land uses generally decreases from Chicago to suburban Cook and DuPage Counties (appendix 3). Similarly, the percentage of trees in good to excellent condition across all land uses gradually increases from Chicago (59.9 percent) to suburban Cook (65.4 percent) and DuPage (67.7 percent) Counties.

The most notable difference in tree condition among the three geographic areas is in their street tree populations (appendix 3). Only 71.3 percent of the street tree population in the Chicago area was classified as in good to excellent condition. This proportion climbs significantly for the street tree populations of suburban Cook (82.9 percent) and DuPage Counties (85.3 percent). This gradient in street tree conditions is most likely the result of differences in tree maturity across the three areas. The street tree population in Chicago contains a higher proportion of large, mature trees likely to be in declining condition (appendix 3). The health and condition of this street tree population also may reflect harsh environmental conditions common in densely populated, highly developed areas.

Through time, older areas may exhibit a decrease in tree cover as mature trees, remnants of past planting programs, decline and are removed. Thus, generalizations about forest structure based on the duration of the land use are limited. The specific site history (for example, planting schedules, storms, and outbreaks of insects and disease) plays an important role in determining current attributes of urban forest structure.

Management Activities

A critical factor in determining urban forest structure is the nature of management activities (Sanders 1984). In areas where management activities are limited, natural regeneration, growth, and development processes dominate and strongly influence vegetation patterns. Under these conditions, future forest structures can be predicted from natural plant succession processes in conjunction with alterations to succession from byproducts of urbanization (for example, pollution, increased temperatures, introduction of exotic species) (Nowak 1991).

In areas where vegetation is managed, management practices combine with plant succession and developmental processes to shape vegetation structure. Many factors influence the type and frequency of management activities that occur on parcels of urban land. These factors include (1) land use (What vegetation structure enhances the functions of the land?), (2) ownership (Is the land publicly or privately owned and managed?), (3) available resources to maintain and manage vegetation (funds, equipment, and information), and (4) goals of vegetation managers (What benefits do land owners want from urban vegetation?).

Because individual land uses often involve similar goals and management practices, characteristic patterns of vegetation and other resources tend to occur within land uses; for example, vegetation on residential properties often is managed to provide aesthetic quality, privacy, shade, places for relaxation, and liability reduction. These goals often yield the controlled and well-maintained landscapes seen in residential neighborhoods across urban areas. In these areas, management activities, such as tree planting and removal, lawn mowing, and use of herbicides, directly alter urban forest structure. Other land uses, such as nature preserves and vacant areas, may have limited or no management activities; these areas are more likely to have vegetation patterns driven largely by natural forest succession.

Forest structure also can vary *within* an individual land use. This variation often is the result of differing management goals and activities among different tracts and land owners. For public urban forest holdings, citizen input and perceived public interest affect the overall management goals (for example, to decrease liability of damage by trees or enhance public recreational opportunities). If the land is privately owned, the type and frequency of management activities are determined by the land owner's specific goals, personal preferences, knowledge, and available resources. One homeowner may take great pride and have ample resources to invest in intensive care of his or her yard, while another resident may prefer to leave vegetation on his or her property largely unmanaged. Because goals, preferences, and financial resources differ among the multiple owners of the urban forest, the extent and condition of forest resources can differ considerably across a land use, even at the neighborhood or block level.

The large-scale variation in urban forest resources is partly a function of the different planning and land use zoning decisions made for particular areas. These decisions govern the configuration of land uses and ultimately influence the systemwide interactions among land uses, land owners, and management activities. Understanding the effects of previous city planning and land use zoning decisions on urban areas and their forest resources is a crucial step in designing new management programs to improve the urban environment. Through recognition of the relation among land use, land owners, management activities, and forest structure, future plans may be developed to either continue previous successes or avoid past mistakes.

Resource Connections Within and Across the Urban System

The data from Chicago, Oakland, and other U.S. cities illustrate how urban forest resources can differ across various land uses and varying degrees of urban development. Contributing at least as much to the complexity of the urban ecosystem are the connections among these resource components within and across urban areas—connections involving vegetation and wildlife, people and institutions, buildings, roads, and utilities. These links may bring desirable outcomes (psychological benefits to people from trees) or undesirable ones (conflicts between trees and utilities). Urban natural resources combine across the urban system to influence landscape-level attributes such as air and water quality, microclimatology, wildlife habitat, recreational opportunities, the risk of fire and outbreaks of insects and disease, and numerous urban-wildland interactions.

The connectedness of the urban forest is easily observed at the site scale. People and wildlife are influenced by vegetation—trees and shrubs provide aesthetic quality, shade, opportunities for recreation, and other benefits to urban residents while supplying food and shelter for animals. Urban infrastructure is affected by vegetation— trees can buckle roads and sidewalks and can grow into power lines and water and sewer systems. Vegetation is influenced by people, their institutions, and their developments—residents manage their properties; they establish regulations and agencies to plant, maintain, and remove vegetation; and people alter existing vegetation with the development of new neighborhoods and shopping malls to accommodate growth.

The interactions among these elements extend beyond the site scale and link properties and land uses across the urban system. Corridors of trees and associated resources can connect land uses along rivers, greenways, and transportation routes (Gobster 1995, Gobster and Westphal 1998, Westphal 1997, Westphal and Gobster 1995). These corridors often facilitate the movement of wildlife and people and may be attractive areas for outdoor activities including hiking, walking for pleasure, and observing nature. At the same time, trees can form boundaries between different land uses, such as screening commercial and industrial areas from nearby residences. Loss of these screens has led to conflict and controversy involving those who live nearby (Gobster 1997, Ross 1997, Shore 1997). Trees and associated resources perform the joint functions of partitions and bridges throughout the urban environment.

In many instances, the management and use of adjacent holdings are linked. Residential resource management may be strongly influenced by the management of nearby residences, street trees, parks, and forest preserves. Similarly, the management of street trees, parks, and forest preserves may be influenced by nearby residential landowners.

Urban forest research shows that forest resources interact across an urban area to have a cumulative effect on several important attributes at the landscape level. The structure and function of vegetation at a broad scale can influence livability of an urban area as well as the quality of the extended environment. Connections among urban forests and other components of the urban ecosystem can influence features such as the following:

Air and water quality: Industrial properties, automobiles, and tree canopies interact to influence air quality in urban areas and beyond. Trees can influence air quality by reducing temperature, removing air pollutants, emitting volatile organic compounds that contribute to formation of ozone and carbon monoxide, and altering building energy use, which subsequently affects pollutant emissions from utilities (Nowak and others 1998). In addition, the mix of tree canopy and other ground covers, such as buildings, paved surfaces, and vegetation, throughout an urban area can significantly influence the runoff from precipitation. Changes in tree canopy and ground cover can have serious implications for flooding and the need for water retention and flood control structures (Neville 1996, Sanders 1986). Urban forest management activities and use also can influence air and water quality. For these reasons, the management of urban trees and associated resources can be an integral part of air quality and water resource management across an urban system and beyond.

Local climate: Urban forests affect local climate, including air temperature, wind speed, relative humidity, and ultraviolet radiation loads. The presence of trees and other vegetation in urban areas can help to offset the formation of urban heat islands (Moll and Berish 1996). Accordingly, appropriate urban tree selection, design, and management can positively influence the urban atmosphere and the health and well-being of urban residents (Akbari and others 1992, Heisler and others 1995, Nowak and others 1998).

Wildlife habitat: A number of holdings in the urban environment may collectively form critical habitats for wildlife. The optimal configuration of habitat can differ widely with wildlife species, but an intricate system of tracts and corridors throughout an urban area often provides habitats and the means for wildlife to move through the urban system. Sightings of deer and other animals throughout many urban systems offer ample evidence of these phenomena. Management of wildlife habitats for particular species may require an approach encompassing the entire urban system with an understanding of its relation to surrounding areas.

Opportunities for outdoor recreation: The interactions among people, their developments, and natural resources can influence opportunities for outdoor recreation in urban areas. The holdings may include extensive areas and corridors, such as corporate and educational campuses, zoos, parks, and nature trails, where sports, hiking, and nature study are popular. Environmental education programs administered in these areas can help to connect people with natural resources in the urban environment.

Risk of fire and outbreaks of insects and disease: Fires, insects, and diseases do not recognize boundaries between land use types in urban forests or between urban and exurban ecosystems. Vegetation structure and management in one area can influence the extent to which outbreaks can affect surrounding areas (Nowak 1993b, Nowak and McBride 1992). Consequently, the prevention of fire ignition and spread and management of serious insect or disease problems in urban areas often require a systemwide approach. This has happened with Dutch elm disease (*Ceratocystis ulmi*), gypsy moth (*Lymantria dispar*), oak wilt (*Ceratocystis fagacearum*), and the Asian longhorned beetle (*Anoplophora glabrapennis*).

Urban-wildland interface interactions: The system of forests with which urban residents interact is continuing to extend beyond the boundaries of urban areas (Bradley 1984, Ewert and others 1993). This expansion has brought urban needs, concerns, and impacts to the attention of many natural resource managers. Increasing urban influences on previously exurban areas not only requires managers to consider the needs of their growing urban constituency but also forces them to adjust their management tactics to address the environmental consequences of urban expansion (for example, soil compaction, litter, pollution, and introduction of exotic plants and animals). The increased attention given to urban National Forests reflects this trend.

The combined influences of vegetation and wildlife, people and their institutions, and urban infrastructure on the large-scale attributes listed above ultimately determine the overall character of an urban area and its surrounding environment. Changes to the elements of the urban system can significantly alter landscape features because of the complex interactions involved.

Consequences of Urban Expansion

As urban development expands into rural areas, many of the land use and vegetation patterns, influences, and interactions previously described for cities move outward. The attributes of forest resources in urban areas provide a forecast of the natural resource health, use, and management issues likely to emerge with development of rural areas. By understanding urban issues and influences, forest resource managers can anticipate changes in exurban areas as they develop. This forethought is critical to establishing appropriate management plans for an urbanizing ecosystem.

Changes in Human Population and Distribution of Land Uses

Urban expansion is inherently associated with increases in population and population density. These changes trigger a diversification of land uses as residential neighborhoods, associated developments (commercial and business, utilities, parks, schools, and religious institutions), and additional infrastructure (sewers and power lines) are constructed to accommodate growth. The expansion of business opportunities, establishment of transportation corridors, and immigration of new residents to developing areas brings an influx of financial, natural, and human resources.

Changes in Community Desires and Management Goals

With the influx of new land owners and resources comes an array of needs, concerns, perceptions, and management goals. As the urban forest is increasingly shared among multiple owners, conflicts regarding desired urban forest structure and function likely will emerge. Systemwide management becomes increasingly difficult without specific programs to coordinate management efforts.

Changes in Forest Structure

Because different land uses contain a range of vegetation covers, the expansion of cities brings an increased variability in vegetation cover types and available growing space. Changes in land use also may include direct tree and forest removal, such as clearing land for residential development, or bring efforts to increase tree cover (for example, tree planting in residential areas or parks). Further, with the detrimental effects of increased land and resource use (such as soil compaction, soil contamination, and other pollution), the introduction of new hazards, including diseases, non-native insects, and fires, may reduce the extent of tree cover in the developing area.

Postdevelopment replanting efforts may replace mature forest resources with new trees and shrubs, thus changing the distribution of young vs. old, small vs. large, and healthy vs. dying trees within the developing area. The introduction of non-native pests and pathogens also could affect the proportion of healthy vs. dying trees. Selection of non-native tree species for planting or accidental transport of non-native competitive species via railroads, cars, and ships can alter the species composition of the developing area over time. Detrimental environmental impacts from development activities (such as erosion, flooding, and trampling) also may affect the quality of existing forest resources.

Changes in Local and Regional Landscape Connections

By directly impacting the physical, biological, and social elements of the ecosystem, the interactions among these elements are likely to change. Because these connections shape the overall character of the environment, the expansion of urbanization has landscape-level consequences; both the removal of vegetation and the resource intensity of urban development impose substantial pressures on the environment. Air and water pollution, soil erosion, solid and hazardous waste, and urban heat islands are just a few of the potential impacts from the expansion of urban areas.

City planning and land use zoning efforts affect the extent and distribution of urban forest resources over an entire urban area. The distribution of land use patterns affects the configurations of forests across an urban area. Sound planning and zoning can minimize some of the negative impacts associated with urbanization.

Review

Urban forests are complex ecosystems. Trees and ground cover, buildings, infrastructure, wildlife, and human populations all contribute to the diversity of urban forests, interacting to create intricate relations among the components of the system. These interactions influence the character of an urban area, affecting attributes such as air and water quality, local climate zones, wildlife and wildlife habitat, opportunities for outdoor recreation, the risk of fire and pest outbreaks, and urban-wildland interactions. The unique physical, biological, and social elements of each neighborhood create vegetation structures that differ across the entire urban area. The extent of tree canopy, species composition, tree sizes, and tree condition changes across the urban landscape, adding to the complexity of the urban forest ecosystem.

Trees play an important role in urban areas, particularly when connected with other elements of the urban environment and natural resource systems. Trees and associated resources can help form bridges, or greenways, among natural areas in the urban environment. Trees also can form barriers that separate land uses, sometimes screening commercial and industrial areas from residences. Forest stands in urban areas also represent avenues for wildlife, hikers, and other recreationists to travel through the urban system and to reach the exurban wilderness.

Multiple factors, including ecotype, land use, duration of land use, intensity of urbanization, and type of management activities, can influence the extent, use, and management of urban forests. These factors affect the space and opportunities for tree establishment and growth, as well as the suitability of environmental conditions to sustain urban forest resources through time.

Comprehensive studies in Chicago and Oakland highlighted substantial variation in the extent, distribution, and condition of urban forest resources across different land uses and among locations within the urban system. This diversity and variability complicate vegetation management by blending the social, economic, and physical attributes of urban systems with natural environmental factors, thereby resulting in connections both across and among urban ecosystems. Because the urban system represents a mosaic of land uses and land owners across both intensely urbanized and less developed lands, the variation in the character of vegetation across an entire system is remarkable. This large-scale variation in forest resources across urban areas is partly a function of the different planning and land use zoning decisions made for particular areas. These decisions govern the configuration of land uses, and ultimately influence the systemwide interactions among land uses, land owners, and management activities.

The expansion of urban areas into less developed rural areas brings several important changes to the surrounding environment. Diversification of land uses, increasing intensity of development, increasing populations, and influx of financial and material resources all accompany urban sprawl. The expansion of urban centers brings alterations to the extent of tree cover, species composition, the configuration of the forest and associated resources, and distribution of tree age, size, and condition. The resulting forest becomes a hybrid of remnant trees and newly established vegetation across the urban landscape.

Chapter 4: Temporal Change in the Urban Forest

Introduction

Human activities and natural events combine to change the urban forest landscape over time. These changes, in turn, influence the direction of resource management and the flow of benefits from urban forest resources. By identifying the forces for change important in the past, planners and managers can anticipate and prepare for pressures likely to influence the structure, management, and use of urban forests in the future. Management efforts can enhance urban forests and their benefits by minimizing or moderating undesirable changes and encouraging favorable changes. Because many of the important forces for change in the urban forest result from individual choices and public decisions, cooperation among forest managers, planners, government agencies, and the public is critical to effectively manage the urban forest ecosystem over time.

The forces that can alter urban forest structure, management, and use over time can be classified into four general categories: direct human, indirect human, direct natural, and indirect natural (Nowak 1993b). Human forces include activities that either directly change the character of the urban forest (for example, tree planting and removal) or indirectly transform forest structure through alteration of land use patterns, human preferences, or the physical environment. Direct natural forces include weather events, fire, and insects. Examples of natural phenomena that indirectly modify urban forest structure and management are population and demographic shifts that may occur in an area owing to the influx of people from areas where natural disasters have occurred.

Direct Human Forces

Urban forests differ most markedly from exurban forests in that the forces exerting the most influence on their structure, use, and management are direct human forces. The relative impact of direct human forces varies across urban areas, with city centers and the urban fringe often the most heavily affected.

Urban Resident Involvement in Tree Planting and Maintenance

Urban tree planting and maintenance are important direct forces for change in the urban forest. Urban residents own and manage a majority of the urban forest resource in most cities. They consequently have a tremendous influence on forest structure. In addition, more residents are becoming involved in the management of public urban forest resources. Community-based forestry programs facilitate citizen involvement in planting and maintenance of public trees along streets, in parks, and other areas (for example, TreeKeepers) (Dwyer and Schroeder 1995; Grove and others 1993; Nannini and others 1998; Schroeder 1998; Sommer 1997; Sommer and others 1994, 1995; Westphal 1994, 1995a, 1995b; Westphal and Childs 1994).

Plant Community and Species Preferences

Citizen preferences for the composition, size, and location of urban forests can significantly influence urban forest structure in parks, in natural areas, at schools, at churches, and in residential neighborhoods. Particular species or plant communities often become popular among urban residents. Popular urban tree species currently include red maple (*Acer rubrum* L.), green ash (*Fraxinus pennsylvanica* Marsh.*)*, callery pear (*Pyrus calleryana* Decne.), honeylocust (*Gleditsia triacanthos* L.), crab apple (*Malus* spp.), and Norway maple (*A. platanoides* L.) (Nowak and Sydnor 1992). Another trend in urban natural resource management that is influencing species composition is a growing public interest in restoring, protecting, and maintaining native plant communities (Gobster 1997; Nassauer 1993, 1997; Raffetto 1993; Ross 1997; Shore 1997).

Influx of Funds to Plant Trees and Other Vegetation

Funds from a wide range of sources have become available to facilitate tree-planting projects of varying scales. In addition to supporting tree planting projects, the allocation of funds to municipal park and public works agencies also finances long-term maintenance programs for urban forest resources. Frequently, funds for tree planting are more easily secured than funds for subsequent tree maintenance and long-term forest management. Because both external and internal funding sources for urban forest management can fluctuate, urban forest structure, condition, and character may change considerably over time.

Management of Urban Infrastructure

Relocation, maintenance, expansion, and upgrading of roads, power lines, pipelines, water management structures, and other components of the urban infrastructure have important implications for change in the urban forest. Many urban trees are found along streets, within utility rights-of-way, and in other areas where much of the urban infrastructure is concentrated. The installation, replacement, and removal of electrical cables, sewers, and gas pipelines can result in substantial alterations to surrounding vegetation. These influences can occur both above and below the ground and are particularly significant in developing areas.

Some utilities are experiencing failures of underground cables installed in the 1970s. Since the installation of these underground utilities, landscapes have matured in the areas surrounding them. The spread of tree roots and shrubs into utility systems complicates the removal and replacement of infrastructure elements and often causes utility management to significantly modify the entangled vegetation (Goodfellow 1989).

Continuous alterations to urban infrastructure can drastically change the urban forest, not only through direct removal, modification, or damage to existing trees, but also through the creation of opportunities for establishment of new vegetation in areas where infrastructure has been abandoned (such as deserted roads, railways, and parking lots).

Land Use Change

Perhaps the most powerful human force directly influencing urban forest structure is land use change. Developments to create residential neighborhoods, parks, and related land uses directly influence forest structure and associated management activities. The expansion of residential neighborhoods into areas with a heavy tree canopy cover can change urban forest structure by removing existing vegetation to provide space for new residences and their associated infrastructure, and through the subsequent planting of vegetation after the development is established. The amount, configuration, and condition of urban forest resources within a particular land use also may change over time. In some areas of the United States, particularly in the Midwest and parts of the West, cities continue to expand into previously cleared croplands, pasture, and rangeland. In these areas, residential tree planting associated with urbanization increases the extent and density of tree cover. For some cities, the movement of people and industrial and commercial developments out of inner city areas brings transformations in the inner city land use and urban infrastructure that create opportunities to establish new natural areas. These changes may provide space for tree planting and natural regeneration of forest resources.

In many regions of the United States, cities are extending into surrounding forested landscapes, thereby causing substantial changes to the character of existing forests. As rural and heavily forested areas continue to experience high rates of population growth, the diversification of land use patterns from urban expansion likely will trigger additional changes in forest resources over time. Because they impose urban pressures on resources outside of urban areas, these developments link forest resources and management issues in urban centers with those in exurban areas. Not only are resources altered by urban development and the associated land use changes, but these changes also influence the types and urgency of management issues across the landscape.

Development of New Urban Forest Management Techniques

Developments in management techniques (for example, plant propagation, tree planting and removal techniques, and insect and disease controls) can bring changes in the structure and health of urban trees and forests. Innovations in pest management programs, for instance, may significantly improve the condition of urban forest resources and increase and prolong urban forest benefits. Changes in the directions of urban forest management also may modify the urban forest structure to correspond with a community's current management goals. Changes in management priorities, as well as improvements in the means of achieving urban forest benefits, can bring considerable variation in urban forest structure and management.

Indirect Human Forces

Increased Interest in Quality of Urban Environment and Urban Life

Research on the environmental, physiological, psychological, health, and social benefits of urban natural resources indicates that urban forests can be instrumental in maintaining and improving environmental quality and human well-being. Increasing concern for the quality of the urban environment and urban life is expanding interest in the contribution of urban trees to these concepts. As a result, many partnerships among urban residents, municipal officials, and agencies concerned with natural resources, environmental quality, human health, and social well-being have been established (Bradshaw 1995, Loomis 1995, Piotrowski 1995, Westphal 1995a). These efforts involve a wide range of state and Federal agencies and their local partners in the management of urban forests. Community partnerships indirectly alter the extent and quality of urban forest resources by facilitating citizen participation in natural resource management. Involvement in urban forestry projects may provide a catalytic boost to other community improvement activities, particularly in communities lacking cohesion or feeling disenfranchised from traditional government programs.

Elevated citizen concern regarding the contribution of trees and forests to environmental quality and human well-being in urban areas also can have an impact on management of forest resources outside urban areas. The interest and participation of urban residents in urban forest management can encourage concern, enrollment, and political action in large-scale regional natural resource issues. Increasing environmental awareness among urban residents can indirectly alter forests in exurban areas by promoting participation in the development and implementation of natural resource policies and management programs.

Changing Character of the Urban Population

Changes in the character of the urban population often trigger alterations in the management and use of urban forest resources. Some of the differences in preferences between past and current residents may be associated with age, income, education, and racial and ethnic background. Increases in the age and racial and ethnic diversity of a community are associated with differences in the types and frequency of leisure activities, travel patterns, and the use of urban forests and other outdoor environments (Dwyer 1994). Such population shifts may result in altered trends in public use of parks and other open spaces, as well as changes in public interest and participation in a wide range of resource management activities.

Changing population characteristics also can influence the extent to which residents benefit from the effects of urban vegetation. The contributions of urban vegetation to air and water quality are likely to have a particularly significant impact in communities at increased risk from the detrimental effects of urban development. Investigation of some population and development trends may help to identify areas having the greatest need for certain urban forest benefits; for instance, particulate air pollution has been tied to increased hospital admissions for children with acute respiratory ailments and older people with heart and lung problems (Shprentz 1996). Other individuals more likely to be affected by air pollution are those with preexisting disease, those exposed to outdoor air pollution (Lipfert 1994), and those with an increased susceptibility to the detrimental health effects from air pollution due to both the cumulative impacts of their depressed socioeconomic conditions (for example, malnutrition, poor living conditions, and emotional stress) and their continued exposure to other urban environmental stresses (Sexton and others 1993). These at-risk populations are likely to benefit substantially from reductions in air pollution that can be provided by urban trees. To address the changing needs of an urban community, urban forest managers need to be aware of areas with environmental health issues, susceptible populations, and how they both change over time.

Urban to Rural Migration and New Developments Across the Landscape

The migration of urban citizens to more rural settings stimulates the development of new residential neighborhoods, associated infrastructure, and commercial developments. Changes in population and land uses in developing suburban and rural areas often bring modifications to the structure and management of forest resources. Coupled with urban expansion is an increasing range of land uses, which can have direct impacts on ground and canopy cover, available growing space, and other dimensions of urban forest structure. In addition, the changing population characteristics of these urbanizing areas can bring changes in the perceptions and desires of local residents about natural resources and their management. Urbanites who move to new residential communities at the urban-wildland interface or in exurban areas may have different perceptions and attitudes about some aspects of natural resource management than long-time rural residents, who may have environmental concerns and preferences originating from agriculture, mining, timber production, tourism, and associated “rural” activities. Urban residents who move to interface or rural areas may take a strong interest in forests and the benefits that they provide in urbanizing environments. These individuals may be important catalysts for changes in forest resource management and use.

The establishment of new residential developments in and near forests frequently influences forest structure and management strategies. Homes intermingled with a forest environment can impose new hazards to forest health, including an increased risk of forest fires, as well as the introduction of insects, disease, and exotic plants and animals. Residential developments near forests also can trigger increased forest use, leading to trampling and compaction of forest soils and vegetation; creation of edge habitats due to opening of forest stands for development; introduction of exotic plants and animals; increased pet predation on wildlife; and increased releases of pesticides, herbicides, or other toxic substances that may impact forest health. These factors can directly affect forest structure, functions, and management needs.

Byproducts of Urbanization

Significant amounts of materials and energy are used to develop and sustain the urban ecosystem. The use of energy (primarily fossil fuel) and other natural resources produces byproducts, such as air and water pollution, carbon dioxide emissions, and heat, that alter the local, regional, and global environment.[1] These modifications (global climate change, reduced stratospheric ozone, and associated increase in ultraviolet radiation and air and water pollution) can impact structure and health of vegetation. Plant communities may change according to their ability to adapt to changes in microclimate and pollution levels.

Involvement of New Individuals and Groups in Forest Management

An increasing number of public, private, and not-for-profit groups are becoming involved in the management of urban forest resources. Much of the involvement has resulted from a growing recognition of the significance of urban forest benefits. Many groups have assembled as part of community-based beautification and revitalization efforts. The benefits that individuals and communities receive from their involvement in establishing and managing urban forests have become important considerations in the development and enhancement of urban communities (Bradshaw 1995; Grove and others 1993; Loomis 1995; Piotrowski 1995; Schroeder 1998, Sommer and others 1994, 1995; Westphal 1995a, 1995b).

Many early volunteer efforts in urban forestry were in response to cutbacks in local public forestry programs. Those efforts have subsequently led to more widespread undertakings, including partnerships that involve volunteers, community groups, public agencies, and private groups in projects to support and improve the effectiveness of urban and community forestry programs. Expanded training of volunteers has enabled these groups to take on an ambitious agenda (Ross 1994), thus increasing the impacts on the structure and management of the urban forest.

New Developments in Measurement and Monitoring Tools

New developments in remote sensing, global positioning equipment, resource inventory technology, and geographic information systems offer significant promise for improved and expanded measurement, monitoring, and mapping of the urban forest and associated resources. These tools could provide managers and planners with an increased ability to obtain relatively low-cost, accurate information on the status and trends of urban forest resources. The ability to effectively monitor the structure of the urban forest and document trends over space and time is likely to have a significant impact on forest resource management. An improved information base regarding the urban forest resource could lead to considerable advancements in managing urban forests to increase the flow of provided benefits.

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[1] Birdsey, R.A.; Alig, R.; Adams, D. Mitigation options in the forest sector to reduce emissions or enhance sinks of greenhouse gases. Manuscript in preparation. R. Alig is at the Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR 97331.

Direct Natural Forces

Extreme Precipitation or Temperature Events

Episodes of extreme precipitation or temperature are likely to have a direct influence on the survival, growth, and development of the urban forest. Communities enduring droughts, flooding, and freezing rain and temperatures frequently experience substantial loss of urban forest resources. Some of the problems caused by extreme intensity or duration of precipitation and temperature events can be reduced by planting species able to tolerate these extremes (for example, drought-tolerant or winter-hardy species).

Storms and Other Natural Disasters

Just as extreme temperature and precipitation events can impact urban forest health, the frequency and intensity of storms (high winds, thunderstorms, ice storms, tornadoes, and hurricanes) also can cause considerable damage to the forest structure. Although relatively little can be done to prevent vegetation change in severe storm events or other natural disasters (earthquakes, volcanoes, etc.), some forethought about species selection, location, and management can reduce the impacts (Andresen and Burban 1993).

Fire

Urban wildfires can pose a significant threat to the extent, structure, and health of urban forests (Laughlin and Page 1987). Fire episodes may become increasingly common as urban developments expand into areas where wildfires are common (for example, chaparral vegetation) (Lotan and others 1978). Vegetation structure can be managed, however, to help reduce the spread of wildfires in urban areas (Fischer and Arno 1988).

Natural Regeneration

Natural regeneration is an important force for change in some urban forests, particularly in areas of the country where trees naturally regenerate (for example, in forest ecotypes) and management practices do not control or limit regeneration (for example, mowing grass). This natural force for the establishment and evolution of the urban forest is especially evident in land uses containing a considerable amount of available space for tree establishment and growth, such as vacant lands, transportation and utility corridors, uncultivated agricultural lands, and natural areas and preserves.

Aging of the Existing Forest

Extensive tree planting efforts in an urban area over a short time often lead to an even-aged urban forest structure. At maturity, such forests may be subject to substantial losses, within a limited time frame, due to tree decline, mortality, and subsequent removal. These even-aged urban forest stands can be found in parks, residential areas, and other surrounding areas and may date to the establishment of the city or neighborhood. Under these circumstances, considerable changes in urban forest structure can occur in these areas over relatively short periods.

Insect and Disease Outbreaks

Outbreaks of insects and diseases can have profound impacts on the urban forest and its management. Several aspects of urban environment and vegetation management practices can influence the potential for insect and disease episodes; for example, urban stresses (air pollution, increased temperatures, compacted soils, and human-induced tree injuries) on vegetation may increase forest susceptibility to insects and diseases (Manion 1981). The proximity of urban areas to natural forest stands and management practices within both urban and exurban areas (for example, pruning wounds, watering, fertilization, forest configuration) can affect the incidence of insects and diseases within an area, their movement between areas, and tree susceptibility to insect and disease infestations (Nowak and McBride 1992).

The frequent movement of people and materials within and between urban areas creates opportunities for distribution of pests. Notable examples of pest dispersal due to human transportation include the gypsy moth, whose egg masses have been spread by people, vehicles, and belongings leaving infested areas (Knight and Heikkenen

1980); the Asian form of the gypsy moth that was introduced at various points in the United States by ships from Siberia and Germany (USDA Forest Service 1994); and the Asian longhorned beetle that was recently introduced into this country via shipments from China (Barden 1997b, Stout 1996). The Asian longhorned beetle is the most destructive forest pest in China and has the potential to significantly alter forest structure, particularly in forests dominated by maples (Barden 1997a). As of June 1998, 2,011 beetle-infested trees had been removed from the New York City area alone. Initial quarantine zones are expanding, as new beetle infestations have been found outside the original zones.[2] In 1998, three separate infestations were reported in the Chicago area (USDA Forest Service 1998a).

Urban forest resources also have been severely damaged by other insects and diseases. Dutch elm disease, for example, has precipitated the loss of many trees, leaving parts of some urban communities barren of tree cover. Species-specific epidemics like Dutch elm disease have revealed the risks involved with limited species diversity in the urban forest. As with the decline of even-aged forest stands, insect and disease outbreaks can markedly alter some urban forests in a short time, especially those with limited species diversity.

Even though urban residents may express considerable concern over forest health, insects, and diseases, human health concerns may limit the range of management responses, particularly the use of chemical pesticides and other pest management techniques.

Indirect Natural Forces

Although the immediate impacts of indirect natural forces for change in urban forests are relatively modest, their long-term effects on urban forest structure can be important. Major natural disasters may displace human populations into new locations. These demographic shifts and associated developments can trigger alterations to the urban forests in areas experiencing a new population influx. Isolated natural disasters also may alter the regional environment and impact forest health in other ways; for example, the heat, ash, and chemical emissions from volcanic eruptions can indirectly degrade forest health in surrounding regions by changing environmental conditions (acidic and particulate deposition). Though not likely of immediate concern, the total impact of indirect natural forces over time can bring significant modifications to the use and management of urban forests.

Both human and natural forces can directly and indirectly impact the structure and management of urban forest resources. Whether from cumulative impacts of human activity or the immediate consequences of natural disasters, the extent, shape, and characteristics of urban forests constantly change to present new issues, questions, and opportunities for management. With the fluctuation of human and environmental pressures over time, changes in urban forest resources can occur gradually or suddenly. An understanding of the potential forces for change in an urban forest requires knowledge of the local population, environment, and history.

Examples of Temporal Variation in an Urban Forest

Detailed information on the history of urban forests in the United States is scarce (for example, McPherson and Haip 1989, McPherson and Luttinger 1998, Nowak 1993b). Data regarding trends in urban forest management also are limited (for example, Kielbaso 1990, Tschantz and Sacamano 1994). Although specific details on the history

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[2] Personal communication. 1998. Bernard Raimo, entomologist, USDA Forest Service, Northeastern Research Station, Louis C. Wyman Forestry Sciences Laboratory, 271 Mast Road, P.O. Box 640, Durham, NH 03824-0640.

and development of urban forests and their management differ significantly across the country, the general patterns of change encountered in cities are likely to be similar. To provide specific examples of how forces for change influence urban forest structure, the following sections illustrate historical changes in the urban forest resources of Oakland, CA (Nowak 1993b), and the recent alterations to the urban forest of Atlanta, GA (Moll and Berish 1996).

Oakland

Oakland has changed drastically from a preurbanized area (c. 1850) with about 2 percent tree cover to a thriving metropolis with a present tree cover of 19 percent (fig. 18). The species composition of trees was dominated previously by coast live oak, California-laurel, and coast redwood (*Sequoia sempervirens* (D.Don) Endl.) and currently is dominated by blue gum, Monterey pine, and coast live oak. Oakland's tree species composition has increased from about 10 species to more than 350. Tree species diversity, as expressed by the Shannon-Weiner diversity index, increased from about 1.9 in 1850 to 5.1 in 1988.

Many factors throughout the history of Oakland have brought changes in the vegetative structure. A chronology of some of these factors illustrates how many different forces can bring about such changes. The incorporation of the city of Oakland occurred in 1852, but the first two "events" listed in the chronology happened before then.

1500 B.C. to early 1800s: Costanoan Indians (forces for change category: direct human)—The Costanoan Indians deliberately manipulated the vegetation of the Oakland area. They altered the native oak stand composition and its extent by burning vegetation to facilitate the collection of acorns.

1840s: Discovery of gold in California and removal of redwoods (direct and indirect human)—With the gold rush in 1848 came an overwhelming demand for construction lumber, and by 1860 not a single redwood was left in Oakland. Besides decimating the redwoods, the gold rush also brought a large influx of immigrants and began the urbanization of Oakland.

1850 to 1890s: Early city development and destruction of native oak stand (direct human)—The development of a grid street pattern in a stand of coast live oak was a key component of the early urbanization of Oakland. This development gradually destroyed the dominant coast live oak stand. By the 1890s, nearly all the original oaks were gone. As trees and other natural resources were replaced with roads and buildings, the structure of Oakland's forest changed markedly.

1880s through 1920s: Afforestation of Oakland hills (direct human)—The first major afforestation effort in the Oakland hills was coordinated by Joaquin Miller, who purchased 27.92 hectares (69 acres) and proceeded to plant pines, cypress, acacia, and eucalyptus. More large-scale plantings were accomplished around the start of the 20^{th} century for three major purposes: (1) "primarily as a measure against the recurring fires that almost every year swept over the hills..." (Oakland Tribune 1923); (2) to increase the value of land holdings; and (3) to generate revenue from future sales of eucalyptus trees for lumber. From 1910 to 1913, Frank Havens planted between 1 and 8 million trees (mostly eucalyptus) on the hills in and around Oakland for eventual sale to lumber producers. The eucalyptus boom ended in 1913, and the trees were never harvested, so that many of these trees still dominate the Oakland hills today.

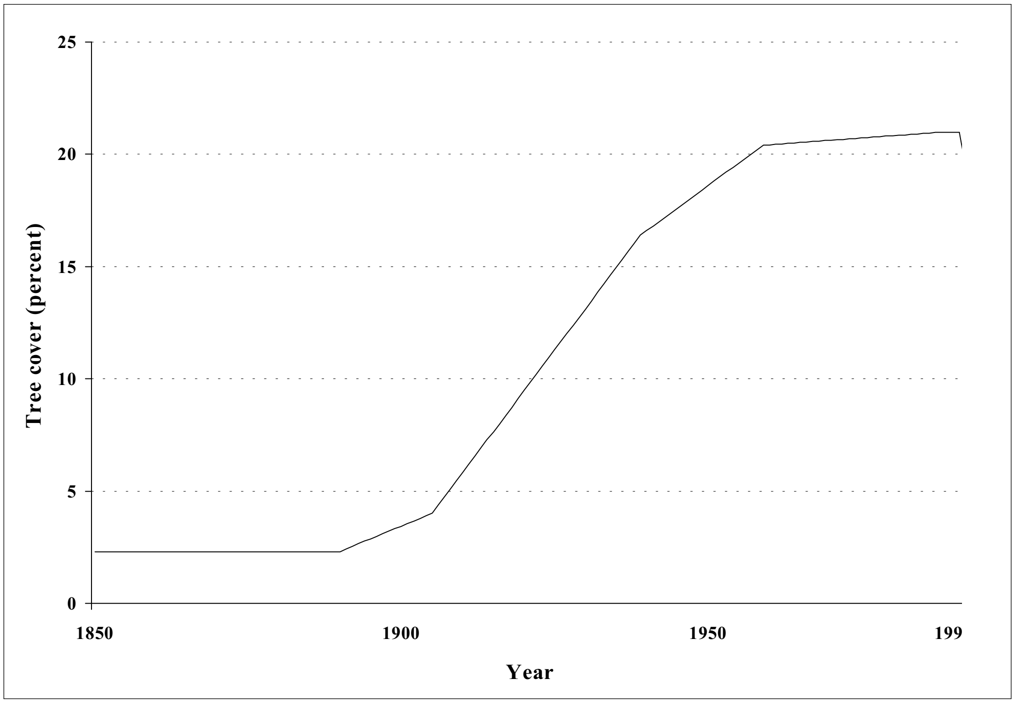

Figure 18—Estimated historical changes in percentage of tree cover in Oakland, CA, based on data collected from 1850, 1939, 1959, 1988, and 1992. Tree cover probably remained relatively static in the late 1800s because destruction of cover from removal of oaks and redwoods was offset by tree plantings associated with new developments and orchards. Tree cover increased around 1900 owing to afforestation of the Oakland hills and continuing development in grasslands. Loss of cover in 1991 was associated with the Oakland fire.

1903: City involvement in street tree planting (direct human)—In the early 1900s, the "city beautiful movement" began. During this period, the city of Oakland gave increasing attention to urban vegetation. In 1903, a citizen committee was organized; it persuaded the city to begin a street tree-planting program.

1906: San Francisco earthquake (indirect natural)—After the 1906 earthquake, a large influx of people relocated to Oakland to escape the damage in San Francisco. This sudden increase in population prompted a housing boom that directly altered Oakland's vegetation in a relatively short time.

1920s: Start of the automobile era (indirect human)—The automobile allowed residents to live farther from places of employment, thereby expediting housing developments outside the city. Oakland rapidly expanded into the surrounding hills during this era. In 1923, the number of dwellings built increased 900 percent over the number built during the previous 5 years. Though indirectly affecting urban forest structure, the use of the automobile and other transportation systems has been a powerful human force in the evolution of urban natural resources over time.

Early 1940s: World War II (indirect human)—World War II brought an increase in jobs, thereby increasing Oakland's population. The war also facilitated a shift in the socioeconomic makeup of Oakland, with a large increase in women and minorities. These alterations to the socioeconomic character of Oakland's population likely prompted changes in preferences for vegetation and its management.

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Fire and fire potential (direct and indirect natural)—A major factor that continues to impact vegetation in Oakland is fire and the threat of fire. Past fires in the Oakland area (for example, 1923—625 houses destroyed; 1970—37 houses destroyed; 1991—3,210 houses and apartments destroyed) have directly altered the urban vegetation structure and increased public concern over fire. The increased awareness among residents of the threat of fire prompted them to remove damaged and dead eucalyptus trees from high fire-risk areas. The removal of vegetation continues as a fire protective measure, and it is likely to bring further alterations to the urban forest structure in Oakland.

The Oakland landscape has changed markedly over the last 150 years (figs. 19 and 20). The change has involved gradual and sudden losses of vegetation, the introduction of new vegetation, and the continuous manipulation and alteration of vegetation structure. Many forces for change in Oakland have been human and have been driven by economic considerations (for example, the gold rush, desire for revenues from future timber sales, urban residential development, and automobiles), though other types of forces have made significant impacts as well. The history of Oakland's urban forest illustrates the many forces that can bring substantial changes to the urban forest and its management.

Atlanta

With their important social component, urban forests are particularly susceptible to human forces for change. The historical review of Oakland's urban forest illustrates a combination of human and natural forces, but a study of Atlanta's changing landscape over the past 20 years focuses almost exclusively on changes from human pressures (Moll and Berish 1996).

Since 1972, Atlanta has grown from a small metropolitan area into a regional trade center. With its expansion, about 65 percent of the previously forested land surrounding the city has been converted into roads, buildings, and other built-up components of urban infrastructure, which has significantly reduced Atlanta's tree canopy cover. Along with reductions in the amount of trees and forests in the area, Atlanta's recent history also is characterized by reduced air and water quality and increased air temperatures (that is, the development of an urban heat island). "In 1972 temperatures in the hottest part of downtown were 6 to 9 degrees higher than in the surrounding countryside. Today not only has the temperature increased, the hot center has tripled in size" (Moll and Berish 1996). Continued growth of Atlanta's urban heat island is expected to increase the costs to cool buildings and to exacerbate existing air pollution problems.

Deforestation and urban development directly impact urban forest structure and can lead to indirect changes in structure as well. With the development and expansion of the urban heat island, the quality, growth, and character of Atlanta's remaining urban forest resources may be altered in response to increased air temperature and pollution. Recognition of the relation between decreased tree canopy cover and the detrimental effects of urban heat islands may prompt future efforts to replace lost cover. In this instance, the activities responsible for expanding the urban heat island would be indirectly responsible for management plans to increase tree canopy cover. Whether directly or indirectly, urban expansion and development have been powerful instruments for change in the urban forest of Atlanta, and they continue to be important factors for change in urban forests across the United States.

Review

The structure of the urban forest changes through time in response to a wide range of powerful forces. These changes originate from diverse human and natural forces operating directly and indirectly on the urban forest and its management. The impact of these forces differs over time and across and among urban systems. This variation often brings very different types and rates of change across urban areas.

In chapter 3, the urban forest ecosystem was characterized as a matrix of diverse resources that intermingle with other aspects of the urban system. With fluctuations in the operation of forces for change over space and time, this matrix can be seen as a kaleidoscope of interacting and changing urban forest structures. Changes in each component of the matrix, as well as the relations among these components across the system, will continue to shape urban forests in the years ahead.

A review of the forces for change in the urban forest highlights an intricate web of connections with other aspects of urban life and a need for coordination of urban forest resource management with many other urban activities: land use planning, residential development, infrastructure development and maintenance, community empowerment and revitalization, environmental education, and efforts to improve other attributes of the urban environment, including aesthetic value, air and water quality, and opportunities for outdoor recreation.

What most distinguishes the urban forest from forests in exurban areas is the dynamic influence of people. Given the inherently slow development of urban trees amid rapid changes to the environments in which they are found, human forces for change pose significant challenges for natural resource planning and management in urban areas.

Chapter 5: Moving Toward Urban Forest Sustainability

Introduction

In accordance with the provisions of the RPA (Forest and Rangeland Renewable Resources Planning Act 1974), this assessment of urban and community forestry provides background information to help guide future policies and programs for sustaining the structure, function, and benefits of urban forests in the United States. The findings of the assessment highlight (1) the large and increasing extent and significance of the Nation's urban forests; (2) the broad scope, complexity, and connectedness of urban forest resources, their management, and use; and (3) a lack of comprehensive information on urban forest resources and their management.

As illustrated by the management model presented in figure 1, planning and management to achieve urban forest sustainability are driven by a constant input of information. This study represents the beginning of a continuous cycle of knowledge entering into the policy, program planning, and management processes. To evaluate the usefulness of this and future urban forest assessments, the following questions should be addressed: What does the assessment reveal about the resource? What do the findings mean? and How can the information be used to guide future policies and programs for sustaining the structure, function, and benefits of the urban forest?

At the national level, this assessment has focused on the extent and distribution of tree canopy and human populations in urban and metropolitan areas across the United States. In the absence of more detailed information about urban forests at this scale, discussions of variation in the character, use, and management of urban forest resources have relied heavily on comprehensive urban forest studies in Chicago and Oakland as well as more limited information from other cities throughout the country. A scarcity of long-term data on trends in urban forest resources, their use, and management also limited the assessment. Illustrations of the dynamics of urban forests and the forces that bring change were drawn from case study data (particularly from the urban forests of Oakland and Atlanta).

This chapter summarizes key attributes of the urban forest that emerged from the assessment and explores their implications for policies and programs concerning urban forest planning and management. The discussion is built around the model presented in chapter 1. Though the information provided in this first assessment of urban forests has been limited primarily to urban forest structure and canopy cover, the ideas and discussions offered in this chapter should provide a solid platform from which future studies may be launched. Policy and program applications of the results are organized into six emphasis areas for working toward sustainability of the urban forest. These themes represent important directions for urban forestry to focus on to maintain or enhance urban forest structure, functions, and benefits. Finally, in light of insufficient information to assess important topics like urban forest health and sustainability, suggestions for additional areas of investigation are presented.

Summary of Assessment Findings

The key attributes of urban forests and forestry that emerge from this assessment are their significance, diversity, connectedness, and dynamic character.

Significance

The urban forest covers a large and expanding area of the United States. About 3.5 percent of the United States is currently classified as urban (that is, urban areas); nearly 25 percent is either located in or functionally tied to urban areas (that is, metropolitan areas). Urban and metropolitan areas grew tremendously in the 20th century. Between 1950 and 1990, metropolitan areas increased threefold; between 1969 and the early 1990s, urban areas doubled in size. Significant population growth in areas outside urban and metropolitan areas continues to extend urban influences to forest resources across the landscape, particularly in places having considerable scenic and recreational value. With this expansion of urban influences, the urban forest resource has increased in extent. As urbanization continues, more forests will come under the direct management of urban residents and institutions.

Urban and metropolitan areas include an extensive amount of forest resources with great potential for significantly improving the quality of the urban environment and well-being of residents. Across the United States, tree canopy cover in urban and metropolitan areas averages 27 percent and 33 percent, respectively, approaching the national average tree cover over all lands of 33 percent. With about 74.4 billion trees in metropolitan areas and 3.8 billion trees in urban areas, the magnitude of the urban forest resource is substantial.

Urban forests can make a considerable difference in the quality of life in a sizable portion of the United States and can directly influence the daily lives of nearly 80 percent of the population. What happens in urban areas also can have a profound impact on forests and forestry across the urban to wilderness landscape. The increasing extent and significance of urban influence across the United States call for resource policymakers, planners, and managers at national, regional, and local levels to focus their attention on forest resources in urban settings.

Diversity

Diversity is one of the most distinctive attributes of the urban forest. This feature is primarily a function of the many components of the urban forest, including trees and ground covers, soil types, microclimates, wildlife, people, buildings, infrastructure, and other developments. These elements are found in almost unlimited combinations in an intricate mosaic across the urban landscape. The elaborate mixture of natural and human-made resources in complex urban ecosystems broadens the scope of urban forestry beyond traditional forestry, arboriculture, and other natural resource disciplines.

The diversity of urban forests is also a function of variations in land uses, land ownerships, residents and visitors, and management objectives across and between urban systems. Urban areas are characterized by multiple land uses and diverse populations; consequently, the management of activities by different individuals and groups creates a complex landscape pattern reflecting an area's unique combinations of physical, biological, and social attributes. With the diversity of land uses and owners in urban areas, the objectives and issues facing managers of the urban forest are wide ranging, extending from wildlife management to the mitigation of air pollution, enhancing aesthetic value, and providing recreation, flood control, fire prevention, and other benefits.

Several factors serve as catalysts for increased diversity in urban forest ecosystems. Shifts in population, changes in economic activity, improvements in transportation, and other developments increase the range of land uses, broaden the spectrum of people involved, and complicate the mixture of old and new, artificial and natural, and native and exotic natural resources in urban areas.

Connectedness

Connectedness among resource components, and with other resources, activities, and functions within and beyond the urban environment, is another key attribute of the urban forest. Other elements of urban environments include roads, homes, industrial parks, and downtown centers. Whether connected by the logistics of managing urban infrastructure (for example, coordinating maintenance of urban trees and power lines, sewers, sidewalks, and roads), or by contributing to the overall character of the area, urban forests link "landscape" with "architecture" and become an important component of urban planning.

The connectedness of urban forests is reflected in their contribution to a wide range of urban issues, programs, and initiatives. Urban forests and their management are connected to programs for improving air and water quality, flood control, energy conservation, microclimate control, aesthetic enjoyment, recreational opportunities, environmental education, and other goods and services in the urban environment. With the many benefits that urban vegetation can provide, the management of urban forests may be linked to an array of other urban initiatives, including urban renewal and community revitalization, economic development, community empowerment, and environmental education.

Urban forests are connected to the condition, use, and management of natural resources in exurban areas as well. Management issues regarding wildlife, fires, insects, and disease do not stay within community boundaries but are shared among managers in both urban and rural environments. Further, many of the externalities of urbanization (such as pollution and acid rain) can affect the health of exurban forests. The designation of the 14 urban National Forests formalized the links between urban and exurban natural resources, as the USDA Forest Service has recognized the effects of urban pressures on areas traditionally considered to be "natural" landscapes.

Finally, urban forests represent a critical link between people and forest resources. Ownership and use of residential holdings, as well as experience with public parks and forest preserves in urban areas, are how many citizens experience, appreciate, and learn about natural resources. The experiences that urban residents have with trees and associated resources in the urban environment are likely to influence their perceptions, expectations, and use of more distant natural resource areas, such as National Forests, parks, and monuments. Experiences with urban forests help to bridge the gap between urban populations and more remote natural environments.

Dynamics

Like all forests, urban forests undergo significant change with the growth, development, and succession of their biological components over time. The growth and development of urban forest resources occur, however, in the context of much more powerful and swift human-induced factors. Coupled with the relatively slow rate of tree growth and plant succession, the swift human forces for change make the dynamics of the urban forest particularly challenging for managers and users.

The expansion and development of urban areas bring important changes in urban vegetation and other urban resources. Alterations to the distribution of land uses, intensity of urbanization, and population characteristics in urban areas result in different combinations of ground cover, increased or decreased opportunities for tree establishment and growth, changing environmental conditions, different resource-use patterns, and altered management objectives. New developments in transportation technology or manufacturing and service industries can bring considerable change to the condition, function, and management of urban lands and associated resources. The introduction of exotic plants and animals into interstate and international trade centers can have a profound influence on the urban forest, as has been the case with Dutch elm disease, gypsy moth, and the Asian longhorned beetle. Changes in the composition of neighborhoods can prompt different approaches to the management of forests in residential areas, parks, and other open spaces. Urban trees are becoming more widely appreciated for their ecological, economic, social, cultural, and historical value throughout the urban environment.

Synopsis of Key Attributes

Urban forests are significant and complex ecosystems with intricate links among their physical, biological, and social components as well as with other elements of urban and natural resource systems. Because urban forests involve trees and other vegetation, buildings and roads, people and wildlife, air and water quality, community empowerment, and other important considerations, the task of sustaining these forests and their benefits crosses disciplinary, jurisdictional, and cultural boundaries. Urban forests are dynamic systems, strongly influenced by the relatively slow growth and development of trees in the context of rapidly changing urban environments. Changes in the distribution of land uses, distribution and composition of urban populations, and objectives of urban forest management simultaneously bring significant alterations to vegetation patterns across the urban landscape.

These findings broaden some traditional perceptions of urban forestry from street tree-planting and maintenance into an essential and highly valued component of large-scale, long-term environmental and community sustainability. In developing management programs to maintain the resource and enhance important forest benefits, the diversity, complexity, connectedness, and dynamics of urban forests must be considered. These features have an array of management implications, particularly regarding the scale of policies and programs, types of management activities, duration of management efforts, links with a wide range of urban initiatives, and number of individuals and groups involved in planning and management of urban forests. The following sections investigate the implications of these key urban forest attributes for the management framework needed to sustain forests, their functions, and their benefits. Findings are interpreted in terms of the planning and management model (fig. 1, presented in chapter 1) to identify opportunities for improvement in policies and programs that encourage urban forest sustainability.

Relevance of Assessment Findings

Because urban forests represent a significant portion of the Nation's natural resource base, their management is a critical component of preserving environmental quality across the country. Urban forest planning and management represents an excellent opportunity to connect people with natural ecosystems and enhance the quality of life for a major proportion of the U.S. population. Once it is established that urban forests in this country are large and growing, are complex ecosystems with diverse resources owned and influenced by a number of important groups, are connected to other urban and natural systems, and undergo significant change over time, implications for planning and management begin to emerge.

The attributes of urban forests reveal a great deal about the type of management needed to sustain their structure, functions, and benefits. The diversity of urban forest resources and their extension across land uses, property lines, and political boundaries call for management programs that bridge jurisdictions and employ multiple disciplines. Among the fields that may be involved in urban forest planning and management are forestry and wildlife management, entomology and pathology, hydrology and soils, meteorology and atmospheric science, landscape architecture, recreation management, psychology, sociology, economics, and political science. Understanding how each discipline relates to the extent, condition, use, and management of urban forests contributes to the development of policies and programs tailored to fit particular situations.

Given the unique character of urban forests in particular settings, effective management requires different forest management strategies within an urban environment (for example, by land use, land ownership, degree of development, and population density) and among urban areas (with different ecoregions, populations, surrounding areas, and other attributes). With the complexity of land uses, ownership, and resources, a "one-size-fits-all" urban forest management scheme is not appropriate for these complex and diverse ecosystems. Managers should develop specific local goals and management strategies to meet the needs of local populations within the context of the local and regional environments and their management.

A key element in managing urban forests regionally is to coordinate activities among different owners and managers across jurisdictions. The participation of multiple stakeholders in urban forest management will rely on the creation of a forum to help link forest structures and their management throughout the urban system and beyond. Such collaborative stewardship not only involves owners, users, and managers of natural resources but also includes individuals and groups involved in the management of other urban components (for example, commercial developers, city planners, nonprofit groups, utilities, and residents). Partnerships among the decisionmakers who affect urban forest resources provide opportunities for those involved to identify common interests, resolve potential problems, and coordinate efforts to meet multiple objectives.

The diversity and connectedness of urban forest resources demand comprehensive approaches to their planning and management. The relation of urban forest components to air and water quality, wildlife habitat, utilities and other infrastructure, and the overall aesthetic character of the community suggests that focusing management activities on a single aspect of the urban forest is likely to yield a decreased flow of some benefits, or other unanticipated complications from management efforts. Thus, the findings of this assessment support the adoption of an ecosystem-based approach to planning and management.

Because urban forests are dynamic systems, their management must accommodate rapid changes in the extent, health, and use of resources over time. Implicit in adaptive management of urban forests is the ability to monitor progress and evaluate the effectiveness of management decisions. To evaluate the efficiency of management activities, management plans should include a way for managers to observe and review the outcomes of their efforts. By monitoring the effects of program activities on the extent, health, and use of the resource, identifying areas for improvement, and modifying management plans to address problems, adaptive management provides the flexibility necessary to sustain and enhance important forest resources in changing urban environments.

The advantages of comprehensive and adaptive planning and management are clear; however, the operation of this method is one of the most difficult challenges facing urban forest managers. Several factors complicate the application of this strategy to management of urban and community forest resources, including the diversity and fragmentation of the resource and its ownership, a lack of consistent information across the urban system and in rural areas, inadequate funding, and different types and levels of resource management across land uses and ownership. Comprehensive and adaptive approaches also are constrained by limited knowledge of the goals and objectives of urban landowners, their interest and willingness to participate in cooperative management programs involving multiple holdings, how forest structure at the landscape level influences local and regional benefits, and how urban forest resources have changed through time. With these limitations, the narrow scope of some urban forestry programs to simply maintain street trees and publicly owned vegetation is not surprising. Yet the current focus on maintaining forest structure on public holdings neither encompasses the entire urban forest nor recognizes the concept of urban forest sustainability.

The concept of urban forest sustainability involves maintaining healthy and functional vegetation and associated systems to sustain long-term benefits desired by the community. Although maintaining forest health and survival has long been a mission of urban forestry, it represents only one component of urban forest *sustainability*. From figure 1, it can be seen that traditional urban forestry practices like tree planting and arboriculture focus only on implementation (fig. 21). If management programs aimed at the health and survival of urban trees and associated resources are administered independently of community goals, they do not represent the convergence of the socially desirable and ecologically possible. Because deciding what to sustain, for whom, and at what scale is the core of sustainability, management for urban forest sustainability needs to incorporate these factors into a decisionmaking process. This task involves broadening current management strategies from simply maintaining forest structure in a particular area to a community-wide effort to exchange information, prioritize benefits, design management objectives, coordinate maintenance activities, and evaluate progress.

Moving Toward Urban Forest Sustainability: Emphasis Areas for the Future

Knowing that the planning and management process for urban forest sustainability needs to be open, participatory, and continuous, the final question remains, How can the information gained from this assessment be used to attain sustainable urban forests? In other words, What specifically can be done to encourage the transition from an emphasis on tree planting and maintenance to comprehensive and adaptive urban forest management? The following sections discuss areas of emphasis in urban forestry that can facilitate comprehensive and adaptive management in the years ahead. Discussions present ongoing initiatives, ideas, and management questions that can help guide the development of comprehensive and adaptive management strategies to sustain urban forest resources and their benefits.

Click here for figure 21

Figure 21—Emphasis areas to encourage comprehensive and adaptive planning and management for urban forest sustainability (adapted from Bormann and others 1994, Lee 1993, Maser and others 1994). Numbers indicate specific emphasis areas.
1. Improving inventory and monitoring of urban forest resources: To generate information as input into the planning and management process, and to provide a way to monitor and evaluate the effectiveness and appropriateness of management activities and objectives.
2. Improving dialogue among urban forest owners, users, and managers: To identify common management goals.
3. Fostering collaboration among agencies and groups: To identify common management goals.
4. Improving the understanding of how forest configuration influences benefits and use: To enable managers to design appropriate management objectives to attain community goals.
5. Increasing knowledge about the factors that influence urban forest health: To discourage reactionary management, thereby allowing managers to effectively work toward management objectives in light of common threats to urban forest health.
6. Improving the dissemination of information about urban forests, their benefits, and their management: To continue the cycle of applied learning necessary for adaptive management of the urban forest.

Improving Inventory and Monitoring of the Urban Forest Resource

Comprehensive inventory and monitoring of the urban forest resource provide an essential base for understanding the Nation's diverse urban resources and how they change over time and for helping to improve resource management and resulting benefits. This management focus has been identified as an emphasis area for several reasons: (1) to address the lack of critical urban forest resource information; (2) to identify forces for change in the urban forest and their influence on the extent, use, and management of urban forest resources; (3) to provide a starting point for development of predictive models to estimate the growth and development of urban forests in the future; (4) to collect information essential to implementation of important urban forest-related projects, such as air and water quality models; and (5) to monitor rates of change, extent, and health of urban forests to provide a foundation for evaluations of adaptive management programs.

Comprehensive urban forest inventories are needed to generate baseline information as input for the planning and management process. Managers cannot begin to effectively sustain structure or function without an understanding of the resource characteristics. Because the urban forest is a dynamic matrix of social, physical, and biological resources, data collection must be comprehensive and continuous to accurately reflect the complex interactions among its resource components.

Besides compiling information to aid the decisionmaking process, comprehensive inventories are necessary to establish links among urban forestry and other urban and environmental programs and initiatives; for example, knowledge of tree leaf surface area is essential to quantify the impacts of urban trees on air pollution and is therefore necessary to link urban forestry with air pollution abatement programs. Similarly, data on the location or spatial configuration of vegetation are needed to guide development of energy conservation and water quality enhancement programs related to urban forestry.

Perhaps most critical is the role that continuous inventories play in the monitoring and evaluation steps of the urban forest planning and management model (**1** in fig. 21). Without periodic inventories, the process lacks a feedback mechanism to monitor the progress of management efforts. Regular inventories are needed to provide detailed data on the extent, condition, and use of urban forests—information against which the appropriateness of management objectives and activities can be evaluated. Because inventories and assessments provide the basis for monitoring, evaluation, and adjustment in urban forestry, their exclusion from the planning and management process immediately breaks the applied learning cycle (that is, adaptive management) needed to sustain structure and benefits in the long run.

Reliable forest resource data to guide development of comprehensive and adaptive urban forest management plans are currently limited. The information available often is fragmented, restricted to street or park tree populations, and incompatible with assessments of rural resources. Consistent information is scarce on urban forest structure, health, management, use, and how these factors change over time. Most urban forest managers are unable to answer even the most fundamental questions regarding the character of their natural resources: What are the composition and health of the city's forest resource? and How do they vary across the urban area? Because no urban forest baseline data sets have been established, trends in the extent, composition, and health of the resource at the local, regional, and national levels are virtually unknown. This scarcity of information makes the development of partnerships to manage forest resources across and between urban systems extremely difficult. In short, the scope and frequency of urban forest data collection are inadequate for meeting the needs of urban planners, designers, managers, researchers, and citizens across the country.

To accommodate the dynamics of resource components, comprehensive inventories of urban forests should involve continuous, long-term monitoring. Permanent field plots and continuous data collection are needed in urban areas to obtain long-term information on change in the urban forest resource. Comparisons of repeated inventories may be used to monitor forest health, observe natural resource trends, and evaluate the effectiveness of management programs at multiple landscape levels. Frequent inventories of urban forest structure throughout the United States are necessary to achieve an adequate understanding of this diverse and important resource and to help develop partnerships and guide comprehensive and adaptive management.

In facilitating easy and accurate estimates of urban tree cover and other urban surfaces, automated remote sensing technologies could significantly improve urban forest inventory and management in the future. Although improvements in remote sensing are being made, the current limitations of remote-sensing digital-image technologies (for example, specialized equipment and training, cost, limited accuracy due to mixed surface types within pixels) suggest that interpretation of aerial photographs may be the easiest and most cost-effective way at the local level to quantify canopy cover and other urban surface attributes. Alternatively, remotely sensed digital images may provide the most cost-effective way to assess canopy cover for large-scale assessments or to incorporate data into geographic information systems. Newer technologies, such as the new generation of digital frame cameras, light detection and ranging (LIDAR, or laser-radar) sensors, and high-resolution hyperspectral digital products offer promise for accurate and cost-effective remote sensing of digital information that could be used to assess urban forests. Nevertheless, because of the multiple surfaces within urban areas, urban tree cover assessments using satellite and other digital imagery need to be tested and improved (Nowak 1993c).

Field data on the composition and specific characteristics of urban forest resources can provide essential information for all land uses throughout an urban system. Even though mapping of canopy cover provides information on the spatial distribution of trees and associated resources, field data should supplement tree cover data with detailed information on tree species, sizes, location, insects, diseases, and health. These data are critical to understanding the resource and can be incorporated into geographic information systems to link the management of urban vegetation with the planning and management of other urban resources (such as transportation systems, utilities, and water quality programs). Given the dispersed nature of the urban forest, its ties with other urban components, and its complex ownership patterns, a combination of remote imagery and field (ground) sampling is the most appropriate data collection technique for urban forest assessments.

Urban forest resource inventories also can be linked with natural resource inventories outside urban areas. With the increasing emphasis on managing forest resources across the urban-rural interface, the use of compatible inventory systems in both urban and exurban areas is critical. In this assessment, estimates of tree cover in urban, metropolitan, and exurban areas, as developed from satellite imagery, were used to provide information regarding the extent and distribution of urban forest resources at national and regional levels. Owing to the relatively high degree of uncertainty of satellite data for small areas, improvements in this technology are necessary, however, to make measurements more accurate at the local level.

Without a strong commitment to improve urban forest inventory and monitoring efforts, information vital for effective urban forest management will be incomplete. The full significance of the resource and its potential contribution to the quality of urban life cannot be realized without comprehensive and regular inventories. In addition to hindering the ability of planners and managers to accommodate change in the urban forest over time, a lack of comprehensive information impedes the development of partnerships among urban forest managers, owners, and users. Without relevant information on air, water, soil, and demographic characteristics of the urban forest mosaic, opportunities for collaboration among residents, city foresters, politicians, environmental agencies, and others to improve the quality of the urban environment may be missed. Infrequent assessments of the extent, condition, management, use, and health of urban forests are likely to impair implementation of monitoring efforts for evaluating the progress of urban forest management programs.

Improving Dialogue Among Forest Resource Owners, Managers, and Users

Given the many stakeholders involved, the diverse and dynamic character of their interests and activities, and the potential for their actions to have a substantial impact on the urban environment, an effective dialogue among urban forest managers and users is critical. The needed dialogue among managers, owners, and users is complex; interaction must occur between groups that are disproportionately experienced and educated in scientific disciplines and that have a broad range of important concerns.

Improved participation of urban forest owners and users in decisionmaking is important for several reasons. First, the values, attitudes, and concerns of urban residents provide the foundation for determining what structure and benefits should be sustained. Thus, participation of owners and users in identifying the goals of urban forest management is fundamental to creating a sustainable urban forest (**2** in fig. 21). If citizen input is omitted from the management framework, the process is highly unlikely to achieve urban forest sustainability. Further, because individual urban residents control a substantial portion of the urban forest, their understanding of how their activities influence the urban ecosystem is crucial to sustaining desired benefits. Open dialogue between the involved parties not only clarifies management issues but also creates a mechanism to enhance information sharing and technical assistance among land owners and community residents. As part of this partnership, managers would have a heightened ability to reduce detrimental human actions in the urban forest (such as improper pruning, unnecessary tree removal, damage to trees, and pollution).

Public participation in urban forest planning and management provides an opportunity to build mutual understanding and trust between residents and managers. Managers can share their knowledge of alternative management options and the possible outcomes; owners and users can share their preferences, concerns, and responses. Participation of urban residents in development and administration of urban forest management activities can yield benefits ranging from increased volunteering and compliance with ordinances to a reduction in the potential for conflict between managers and users over resource use and maintenance (Kuhns and others 1995, Westphal 1995b). The development of alliances between urban forest managers and the public also may open doors for other opportunities to enhance the urban forest, including community grant partnerships, cooperation among agencies and with not-for-profit organizations, and other collaborative stewardship efforts.

The experiences that urban residents have with management and use of urban and community forests can influence their involvement in and support of forest resource management beyond the urban environment. Urban residents who are introduced to natural resource concepts, management issues, and solutions to environmental problems in urban areas are likely to be more aware of similar issues in exurban areas. By enhancing their interest in and awareness of natural resource management issues, resident involvement in local level environmental decisionmaking may increase participation in broader, regional natural resource matters (including informing government representatives or joining environmental and natural resource interest groups). Thus, the participation of urban residents in use and management of urban forests has important implications for the sustainability of forests and management programs beyond the urban environment.

Without dialogue among managers, owners, and users, urban forests may not be managed efficiently. The focus of management efforts on areas or issues different from those of concern to community residents increases the potential for conflict among the involved parties. Lack of an effective dialogue among resource owners, managers, and users also reduces opportunities for collaborative efforts to enhance the benefits that urban forest resources can provide. The absence of communication between urban forest managers and residents also drastically decreases the ability of managers to influence urban forest management in private holdings, thereby resulting in an opportunity lost to significantly enhance the benefits of the resource for the entire community.

Managers and stakeholders can accomplish far more to sustain and enhance urban forests as partners than they can separately or as opponents. Because urban residents ultimately shape management goals, their communication with managers is extremely important for attaining urban forest sustainability. The ability of managers to meet user needs can be enhanced by research on residents' values, preferences, and expectations; however, managing the urban forest structure to meet the unique needs of an individual community also requires open and continuous dialogue among these individuals.

Fostering Collaboration Among Agencies and Groups

Given the many public agencies, not-for-profit groups, and other organizations influencing urban forests, their management, and use, the actions of these entities often have far-reaching implications for the structure, functions, and benefits of urban vegetation. Consequently, collaboration among these players is critical for working toward urban forest sustainability.

Urban forestry can play a critical role in enhancing the sustainability of an urban community. Urban renewal and community revitalization programs have several dimensions to which urban forest management can contribute. Urban trees can contribute to urban improvement programs through microclimate improvement, pollution prevention and mitigation, local economic development, and city beautification. The participation of urban residents in urban forestry programs can facilitate community organization and empowerment, which subsequently strengthen the vitality of an area. The contribution of urban forests to the quality of the urban environment, and the inherent links to other components of urban and surrounding systems, enhance the desirability of integrating urban forestry with the activities of other agencies and groups. Because management of urban forest resources can improve the environmental and social well-being of communities, the collaboration among multiple groups to meet common goals has emerged as an important emphasis area for the future (**3** in fig. 21).

Collaboration among agencies and groups is essential for coordinating the management of resources across jurisdictions and at multiple scales. The implementation of an ecosystem-based approach to management will rely on cooperation among urban residents and community groups, national and local not-for-profit organizations, private businesses and institutions, and Federal, state, and local agencies. These groups need not only to collaborate in the process of defining community goals but also to ensure that their individual activities are not counterproductive to meeting management objectives. By sharing fiscal, administrative, maintenance, and enforcement responsibilities, initiatives to coordinate the activities of multiple actors in the urban environment can significantly improve the efficiency of the overall planning and management process.

Successful integration of urban forest management with other urban initiatives requires partnerships among groups concerned with urban forests, their use, and management. The groups can range from local neighborhood associations to agencies concerned with regional water or air quality. Because the focus and missions of different groups can extend from the inner city to the urban-wildland interface, the roles of the involved parties must be clearly defined for coalitions to work efficiently. Differences in the extent of agency jurisdiction and authority, as well as in group interests, resources, and access to information require the clear understanding of participant roles and responsibilities in cosponsored activities.

In coordinating urban forestry with the efforts of different natural resource and urban-community groups, several key questions regarding group participants, their roles, and the interactions among them emerge: What should be the roles of the different groups? Given the variation in the characteristics and elements of urban forests, should interaction among these groups be cooperative? Multidisciplinary? Multilevel (national to local)? Open? Should a policy framework be created to direct the integration of multiple urban and natural resource agencies and groups? Should partnerships be purely voluntary? Should partnerships include local, regional, and national level organizations, or should they be forged at a single level? What should be the proportion of public participants to private members? The specific roles of the involved participants may depend on their jurisdiction, resources, and access to information. Some considerations in developing partnerships between different groups include group constituents, group jurisdiction and authority, group goals, and group resources, knowledge, skills, and abilities.

Coordinating and identifying specific roles for the numerous groups that influence urban forest management are not easy tasks. Integration of group activities may differ significantly from one situation to another, depending on the characteristics of the urban forest resource, the role it plays in the urban environment, and organizations involved. Many groups aid in coordinating urban forest and urban forestry efforts nationally (for example, Alliance for Community Trees, International Society of Arboriculture, National Arbor Day Foundation, USDA Forest Service State and Private Forestry, American Forests, Urban National Forests, National Urban and Community Advisory Council). At the state level, state urban and community forestry councils, formed by state foresters, provide a forum for various interests to exchange ideas and provide guidance for administering state and Federal programs locally. These councils also encourage partnerships among council members to enhance the management and use of urban forests. Several local urban forestry groups play important roles in the comprehensive management of urban resources. Members of some national groups (like the Alliance for Community Trees [ACT]) also play key roles in coordinating and strengthening the efforts of groups to improve urban forest resources locally.

The grassroots summit, “Growing in Our Urban and Community Forest Movement,” held in Wintergreen, VA (October 25-28, 1998), brought together some important groups in urban and community forestry. Participants included members of ACT, state-level urban and community forestry councils, and other public and natural resource agencies. A major theme of the summit was to work collaboratively to strengthen urban and community forestry at the grassroots level. Other focus areas of the workshop were “strengthening our leadership,” “uniting our purposes,” and “sharing and celebrating our successes.” The summit was sponsored by the National Tree Trust, in cooperation with ACT, American Forests, USDA Forest Service, Virginia Tech College of Forestry and Wildlife Resources, Virginia Department of Forestry, and the Virginia Urban Forest Council.

The community future forum (1998) is a 2-year project involving a diverse group of urban natural resource professionals in identifying and developing management strategies to address natural resource issues in urbanizing communities. The objectives of the forum are to (1) stimulate dialogue that will address future and emerging natural resource issues in and around urban and community areas; (2) provide opportunities for creative thinking and new partnerships; (3) develop a shared urban land stewardship ethic; (4) identify a vision of a future that results in sustainable communities; (5) identify resources, tools, partnerships, and policies that will move us to the desired future vision; (6) construct a flexible, locally applicable national model or framework to meet future natural resources needs; and (7) develop a series of strategies to achieve the vision.

The effort began with an event in Washington, DC, August 25-27, 1998. It united nearly 125 urban natural resource professionals to pursue the forum objectives; the forum continues to encourage collaborative efforts in urban forest research, the development of urban forest policies and programs, and resource management among agencies and groups. Key forum sponsors are the National Association of State Foresters, National Urban and Community Forestry Council, Natural Resources Conservation Service, Pinchot Institute, and USDA Forest Service.

The urban resources partnership (URP), a partnership among Federal agencies and local groups exists within 13 cities to encourage resource management in urban areas at the ecosystem level. The URP demonstrates a wide range of useful approaches for enhancing management of urban natural resources by spawning partnerships involving different participants, organizational structures, and group missions in each of the selected cities. Variation in the types of groups, resources, and resource issues involved suggests that the most effective mix of partners, working relations, and leadership structures in collaborative urban natural resource management can be different for each city. The URP effort also reinforces the importance of community involvement in projects, as well as a strong need for technical assistance to accompany financial assistance to effectively manage natural resources in urban areas.

The number of local partnerships can become large, as illustrated by the 100 or more members of the Chicago Regional Biodiversity Council (or Chicago Wilderness) that work to protect, restore, and enhance biodiversity in the Chicago area. Chicago Wilderness has brought significant attention to the management of more than 80 938 hectares of public and private land in northeastern Illinois, southeastern Wisconsin, and northwestern Indiana. Revitalizing Baltimore, a federally funded urban and community forestry pilot project, also involves several stakeholders in efforts to improve environmental health and the quality of life in that area. Partners in Revitalizing Baltimore work to increase and improve neighborhood vegetation, support environmental education, and encourage community-based environmental research and decisionmaking. Involved groups range from Federal and state agencies to businesses, academic institutions, and not-for-profit organizations. Coalitions such as Chicago Wilderness and Revitalizing Baltimore serve as models for collaborative stewardship of urban natural resources and are attracting national and international attention.

The best organizational framework and roles for the numerous groups involved in collaborative urban forest management are not yet clear. What is clear is that partnerships are an increasingly critical key to effective management of the urban forest ecosystem. Without cooperation among government agencies, not-for-profit groups, utility companies, and other corporate and community groups, increased conflicts over management and use of urban forest resources are almost certain. An absence of coordinated management efforts across an urban area likely will continue to fragment the ecosystem. If collaborative partnerships are avoided, opportunities to cost-effectively enhance the urban environment and quality of urban life will be foregone. Because urban forestry could play an important role in broad community improvement efforts (such as redevelopment of brownfields [abandoned, idled, or underused industrial and commercial properties that may have been contaminated by earlier industry, thereby complicating redevelopment plans with fears of liability and cleanup costs], air quality improvement, and watershed management initiatives), a wealth of funding opportunities for urban forest programs may be missed if expanded partnerships are not developed.

Improving the Understanding of Urban Forest Configuration

Urban forest benefits depend directly on the configuration of vegetation and its location relative to other natural and human-made attributes of the urban environment (urban forest structure). To make community goals operational, managers need to design and work toward a vegetation structure that will provide desired benefits. This requires an understanding of how forest configuration influences the flow of benefits. Knowledge about the relation among forest structure, function, and benefits enables development of management objectives that reflect community interests and identification of the scale needed for management efforts to attain community goals (**4** in fig. 21).

The most desirable configuration of the urban forest resource depends on the conditions and goals unique to each location. Because the desired benefits from urban forests differ among individual communities and across land use types and land owners, the best configuration of trees to provide the needed benefits for one area can be dissimilar from the forest structure required to meet the goals in another area; for example, obtaining particular benefits from trees in an urban park site requires a different landscape design than that needed to secure urban forest benefits in a residential or transportation setting.

The structure of the urban forest influences the provision of important benefits at different geographic scales. The large-scale or landscape configuration of the urban forest is important for providing significant benefits to broad areas, including air and water quality and wildlife habitat. Alternatively, small-scale configurations may be designed primarily for local, more immediate benefits, such as aesthetics, microclimate, energy conservation, or opportunities for outdoor recreation. These local-level effects often combine to affect the entire region. Because urban forests often are managed at multiple scales, management decisions need to consider the complex interactions of management objectives and forest structure in meeting local and regional needs.

To make sound management decisions for multiple benefits, managers need to be aware of appropriate urban forest configurations and management systems for providing particular benefits. Although much has been written about the wide range of benefits that urban trees and forests can provide, knowledge about how to provide specific urban forest benefits in a particular situation is limited. Future research needs to continue the work on benefits and expand on topics involving the environmental, social, and economic costs of providing these benefits. Information on specific forest configurations for maximum net benefits at the local scale also is needed.

Models to predict the environmental functions that may accompany particular forest structures offer significant promise for providing guidelines for forest design and management to enhance certain urban forest benefits. A new urban forest effects (UFORE) model using tree cover and field data from across the urban ecosystem quantifies urban forest structure and associated functions (for example, impacts on air quality and greenhouse gases) across various urban areas (Nowak and Crane, in press). Previously developed models that predict scenic beauty, perceived safety, and probability of human use as a function of forest structure also can be instrumental in developing comprehensive management plans to enhance and maintain the beneficial functions of urban forests (Dwyer and others 1989; Lein and Buhyoff 1986; Schroeder 1982, 1983, 1986, 1988, 1989; Schroeder and Anderson 1984; Schroeder and Cannon 1983, 1987; Schroeder and others 1986).

In the absence of information relating urban forest benefits to forest and landscape structure, urban forest management efforts likely will continue to focus on maintaining urban forest structure with little consideration of design and management options to enhance desired functions. Management plans based on incomplete information about the links among forest structure, management, and beneficial functions can lead to increased costs, reduced benefits, and reduced effectiveness of urban forestry programs in serving a wide range of public and private needs. The absence of this information also will limit potential partnerships among urban foresters, individuals, and other urban or natural resource groups. These outcomes could erode public support for urban forests and forestry over time.

Increasing Knowledge about Urban Forest Health

Inherent in sustaining urban forest benefits is preserving the health of the resource. This emphasis area represents a continuing effort to maintain a healthy and functioning urban forest system as a vital component of sustaining urban forest benefits. This area addresses several critical concerns associated with the vitality and perpetuity of urban forests and their surrounding environments: pests, disease, fire, environmental stress, development, and long-term care for urban vegetation (continued maintenance after tree planting). Besides targeting the key factors that directly affect trees and forest health, this emphasis area also includes research and development efforts to identify and deal with the indirect impacts of human activities (disturbance and pollution) on the extent and condition of urban forests. Thus, programs in this area can provide managers with the means to attain their management objectives given the environmental and human threats to urban forest health (**5** in fig. 21).

Some of the most immediate concerns in maintaining the health of urban forest resources are natural forces, including insects and disease, invasive species, fires, and storm events. Extensive losses of urban trees due to these threats in the past have forced managers to expend significant percentages of their budgets on containment, treatment, cleanup, and replacement activities. Such reactionary management eventually can become counterproductive, as efforts to sustain desired forest structure, functions, and benefits may be foregone to support damage control. Programs to encourage prevention measures and cooperative response to disaster events can allow managers to pursue their management objectives while dealing with forest health issues.

Recent responses to infestations of the Asian longhorned beetle in New York City and Chicago illustrate the importance of collaborative efforts in pest control. Numerous Federal, state, city, and local organizations are working cooperatively to detect and eradicate the beetle from these two areas. In New York, USDA Forest Service programs in State and Private Forestry and in Research, USDA Animal and Plant Health and Inspection Service (APHIS), New York State Department of Agriculture and Markets, New York City Department of Parks and Recreation, and local neighborhood groups have joined forces in fighting this pest (Haack and others 1997, USDA Forest Service 1997b). A similar team approach involving Federal, state, and local agencies is underway in Chicago (USDA Forest Service 1998b). U.S. Customs Service agents are now being trained to detect the insect, which enters the country in infested crates and pallets from China. To control future infestations, the Secretary of Agriculture recently imposed a moratorium on the import of untreated lumber from China, thereby illustrating the far-reaching implications of policies and programs that deal with urban forest resources.

The forging of partnerships within and among communities to control the threat of fire in urban forests is an essential aspect of this emphasis area in several parts of the United States. Cooperation among residents and other land owners to establish fuel breaks for fire prevention represents an important management focus in protecting the health of many urban forests. By sharing the responsibility for discouraging fire outbreaks, managers are able to devote more time and resources to attaining community goals.

Also important in sustaining urban forest health is a better understanding of the effects that urbanization can have on forest health. Soil characteristics, watersheds, wildlife, insects and disease, air and water quality, and meteorological conditions in urban areas may be significantly different from those of rural settings. Recognizing the differences in ecological components of urban and rural forest ecosystems can substantially improve our understanding and management of natural resources in urban environments.

The recent establishment of long-term ecological research (LTER) sites in urban environments (in Baltimore and Phoenix), funded by the National Science Foundation, has affirmed the importance of researching natural environmental processes in urban settings. The research questions that are fundamental to the LTER projects will move both researchers and managers forward in understanding specific factors threatening forest health in urban areas. Some key questions now being addressed include the following: How will the structure and function of an urban forest change over time, given a range of management and ecological restoration techniques? How does urbanization impact the soil, water, air, and meteorological conditions influencing urban forest growth and development? How does natural plant succession in urban areas differ from that in rural areas? What are the life spans of different urban tree species, and what environmental and management factors affect the life spans and health of urban trees?

Another important consideration in preserving urban forest health is the commitment of funds and planning efforts for maintaining trees and other resources throughout their life spans. Fiscal difficulties in municipal agencies often have led to decreased or interrupted funding for urban forest management programs. Without continued efforts to sustain long-term tree survival, substantial tree planting investments can be wasted. Failure to consider the influence of urban infrastructure, growing space, and other natural resource health factors in planning of tree planting programs can hinder the establishment, growth, and development of urban trees and potentially create significant tree-related problems and maintenance expenses in the future. Both the stability of urban forest management budgets and appropriate planning for tree planting and other programs are important to maintain the health of the urban forest resource. Forest resources need to be elevated to a status of critical importance within municipal budgets to cost-effectively sustain the numerous forest benefits over the long term.

Successful management of urban forest health depends on an understanding of the complex connections between natural resources in urban and rural settings. Managers need to recognize, for instance, the vulnerability of urban forests to the same pest, disease, and fire issues of “natural forest environments.” Likewise, managers of exurban forests are likely to experience the effects of development and related influences from urban areas. Air pollution, insects, contaminated water, fire, and other risks to forest health and sustainability are not bound by community borders and therefore call for coordinated management efforts across the urban-rural interface. The recent discovery of the Asian longhorned beetle in New York City and Chicago raises questions about the introduction of exotic species into urban areas, their subsequent spread into other urban and exurban areas, and the strategies needed to control the proliferation of these pests. With expanding international and interstate trade, the risk of such infestations increases.

A critical element of maintaining a functioning urban forest to sustain benefits is understanding the level of human intervention needed to keep the forest healthy. The extent to which managers intervene in natural plant processes depends on the environmental and social conditions specific to their areas. Because forest health issues in desert cities (for example, water issues) may differ drastically from those in cities of grassland or forest ecotypes (such as natural forest regeneration), and because each urban area has distinct needs and problems, prevention and response regimens to protect urban forest health should be developed locally. The type and frequency of management activities needed to preserve forest health are determined by site-specific and regional factors, including ecotype, type and severity of management issues (such as threats of insects, disease, or fire), influence of exotic invasive plants and animals, meteorological or environmental conditions (storms, flooding, pollution episodes), availability of funding and other resources necessary for management, level of expertise, and feasibility of cooperation between residents and managers.

Insufficient attention to maintaining urban forest health may lead to reactive management (that is, managing specific crises without an overall management plan to facilitate sustainability of forest benefits), additional risks to exurban forest resources, and potential conflicts among urban forest owners, managers, and users. Each consequence will substantially increase the costs of urban forest resource management in the years ahead. Without long-term strategies to facilitate the growth and development of urban forests after tree planting programs, the support and cooperation of citizens in future urban forestry efforts likely would decline.

Improving Dissemination of Information

The key to adaptive management is applied learning—a process fundamentally driven by a continuous influx and application of new information (Bormann and others 1994, Lee 1993, Maser and others 1994). Thus, a critical responsibility of managers and researchers is to provide stakeholders, decisionmakers, and users with information to enhance communitywide planning and management. The effective distribution of information is an essential precursor to users (homeowners, planners, educators, and researchers) being able to sustain urban forest benefits (**6** in fig. 21). As groups generate new information on urban forest structure, functions, and management technologies, the need for a reliable mechanism to ensure dissemination in a useful form and timely manner continues to grow.

Improving the dissemination of urban forest information is an important element of comprehensive and adaptive management of urban forests for several reasons: primarily, though, to educate public and private landowners and groups about urban forest benefits, health issues, and management options to enable these participants to make informed decisions in the process. Residents who are aware of the benefits and costs associated with urban vegetation are more likely to achieve the potential for positive urban forest effects on their environment and community well-being. Improved dissemination of information also can be useful in coordinating management efforts across the community. Public education on maintenance techniques, urban forest health issues, and other management topics offers city foresters and others an opportunity to influence the management of vegetation outside their immediate jurisdiction. Because the activities of private residents and other landowners affect a large portion of the urban forest resource, informational programs aimed at these audiences provide managers with a way to enhance benefits from a significant segment of the resource.

While driving the adaptive management of urban forest resources, improved information exchange also can be a critical component of general environmental education for all ages. Circulating pamphlets, providing literature, and hosting public workshops about natural resource issues within the community may generate awareness of similar issues beyond urban areas. These efforts may encourage environmentally responsible behavior among residents, or may prompt citizens to volunteer their resources and efforts toward natural resource-related causes outside their communities.

With the crucial links among forest resources and other components of the urban environment, the variety of benefits they provide, and the number of individuals and groups involved in their management, the exchange of information about urban forests and forestry is a challenge. Though research continues to generate new information on urban forest benefits and management technologies, the application of these findings in the field often is limited. Contributing to this problem are incompatible information systems, differences in technical capabilities, and obstacles to participation in conferences and other continuing education programs. The development of regional technology-transfer and education centers to link researchers, managers, policymakers, and the public can greatly enhance the dissemination of existing and new information about urban forests and forestry. Particularly important clientele for regional centers are urban forest managers requiring information or assistance in developing comprehensive management plans and policymakers needing information on how urban forests affect the health and well-being of cities. Other potential customers are homeowners interested in how to manage their residential properties, and educators who can incorporate urban forest ecological and management principles into their curricula to help develop a better educational base concerning ecosystems.

Because the urban forest resource is complex, variable, and managed by multiple organizations and individuals, some common issues on dissemination of urban forest information include lack of comprehensive information, providing public access to information, timely access to information, data quality, mechanisms for easy data sharing, and other related issues (compatibility, reliability, metadata, methodologies, and misrepresentation). Clearly, gathering information is just one of the issues needing to be addressed in developing a focus on information dissemination. Another key issue is the development of opportunities to exchange and apply the compiled information in a way that promotes effective management and use among urban forest owners, users, and managers.

In identifying the dissemination of urban forest information as a management emphasis area for the future, an array of policy questions on the development of information initiatives emerges: What can be done to facilitate quality information exchange among managers, policymakers, researchers, homeowners, and other individuals? Should a policy mandating certain standards for data quality and methodologies be developed? Should partnerships among government agencies, research institutions, and interest and community groups be created to compile and distribute information? Should community outreach programs be established to apply the gathered knowledge? What measures for quality control of distributed information should be taken? In other words, what policies will provide for the long-term assessments, information sharing, multidisciplinary research, and technology transfer needed to develop and administer comprehensive urban forest management plans?

These questions illustrate the difficulties involved in designing approaches for improving the dissemination of urban forest information, and they identify critical issues for the future of urban forests and forestry in the United States. Without additional efforts to communicate research findings, share innovative management technology, distribute information, and facilitate application of this information to management of natural resources on private properties, opportunities to enhance the urban forest resource will be missed. By limiting the dissemination of urban forest information, open dialogue and the development of partnerships between urban forest managers and community constituents will be hindered. By reducing the effectiveness of open dialogue among groups, inefficient distribution of information also may discourage public participation in urban forest planning and management, curb citizen support of urban forestry programs in the future, and contribute to ineffective management of resources. As citizens of urban areas represent owners, managers, and users of the urban forest, the focus of urban forest management and research efforts on providing people with the information necessary to enhance their environment is a fundamental part of linking people with ecosystems.

All six of the above emphasis areas identify important tasks for encouraging comprehensive and adaptive management of urban forest resources in the future. These focus points not only allow management approaches to be more compatible with the diversity, complexity, connectedness, and dynamics of urban forests but also lay groundwork for broadening urban forestry into a flexible, ecosystem-based management approach to sustaining forest benefits.

Future Urban Forest Assessments

Because this report is the first national assessment of urban forests, it has focused on quantifying the magnitude and variation of this resource and the human population across the United States. Future urban forest assessments can build on this report to enhance knowledge on this Nation's urban forest resource and its management. Areas of investigation for future reports include assessing (1) local attributes of the urban forest resource, (2) the roles and goals of urban residents and organizations, and (3) current management practices used to sustain the urban forest resource and opportunities for improvement. Analyses of these topic areas currently are hampered by insufficient or unorganized information at the national scale.

The Urban Forest Resource

To better assess the current state and trends of the urban forest resource, additional local data on the urban forest resource (that is, number of trees, species composition, tree size, health, available planting space, and urban forest functions) need to be collected across the Nation. These locally specific data will provide information on the current structure and condition of this resource, which can serve as baseline data to determine trends in the urban forest. The establishment of permanent monitoring plots in urban areas can enhance continuous and efficient gathering of information related to urban forest conditions and trends. Once detailed information on urban forest structure, condition, and trends has been developed across the country, an indepth assessment of the national urban forest resource can be completed.

The Urban Social Resource

Although this assessment has presented broad information on population attributes and trends across the Nation, more information on the human and organizational components of the urban forest is needed. Questions to be addressed in future assessments might include the following:

- What is the distribution of the urban forest resource across different ownership groups, and how does this differ across the United States?
- What are the broad management goals of the various ownership groups (for example, residential vs. public sector vs. commercial and industrial owners)?
- How do management goals differ within ownership groups, based on factors such as region of the country and socioeconomic status?
- What other groups beside land owners are involved in developing and imple-menting urban forest policy and management (for example, Federal, state, and local agencies or not-for-profit groups)?
- What are the roles, responsibilities, and jurisdictions of owner and nonowner groups involved in urban forestry?

Current Urban Forest Management Practices

Another task for future urban forest assessments is to compile and evaluate informa-tion on current urban forest management practices across the Nation. This focus could investigate how management practices differ among regions, and evaluate which management procedures are most appropriate for sustaining the urban forest and integrating urban forest owners. Topics covered in this type of study might include determining the effects and degree of impacts of the following variables on the effectiveness of management activities:

- Budgets and funding sources
- Ordinances, policies, and regulations
- Partnerships and public involvement
- Educational programs
- Innovative technologies and programs
- Scope of management (managing street trees, managing all publicly owned trees, or managing all publicly and privately owned trees)
- Scale of management (neighborhood, city, metropolitan area)
- Goals of management

Conclusions

Urban forest resources in the United States are large and expanding in extent and significance. They provide many valuable goods, services, and experiences to the nearly 80 percent of the population that live, work, and recreate in urban areas. In addition, urban forests have ecological and social links that extend the influence of urban forests and forestry beyond urban areas. Involvement by urban residents with urban forests and forestry often influences their perceptions and behaviors about forests and forestry in exurban areas.

Urban forests are highly diverse, connected, and ever changing ecosystems. They are complex environments linked with many other components of the urban system and occur where people, their activities, and their developments play significant roles in altering the physical and social environment. Management of these systems involves a wide range of disciplines, organizations, owners, users, and managers to sustain forest health and desired functions.

Because a principal goal of urban forestry is to sustain forest structure, health, and benefits throughout the urban ecosystem over the long term, comprehensive and adaptive management approaches are needed. For various reasons, current urban forest management often focuses on sustaining a healthy population of publicly owned trees (that is, street and park tree populations). Expanding the management focus of urban forests to all trees and their benefits in the urban ecosystem will be challenging and will require nontraditional urban forest management techniques; however, the overall societal benefits of doing so may be substantial.

Management must be comprehensive in terms of its process, and it must be adaptive to allow for adjustments based on new information. To attain comprehensive and adaptive management, urban forest managers should consider:

- The desires and needs of the community
- What urban forest structure is necessary to best address community needs
- Periodically reassessing community needs and urban forest structure to ensure that management plans remain appropriate

To facilitate comprehensive and adaptive management to help sustain the entire urban forest ecosystem, the following topic areas also need to be emphasized:

- Improving inventory and monitoring
- Improving dialogue among owners, managers, and users
- Fostering collaboration among agencies and groups
- Improving the understanding of how forest configurations influence forest use and benefits
- Increasing knowledge about factors that influence urban forest health
- Improving dissemination of information about urban forests and their management

An important consideration in shifting to more comprehensive and adaptive management practices is whether the vegetation management and maintenance costs will be reduced or societal benefits from vegetation be increased enough to warrant the additional expense of a comprehensive and adaptive management approach. Because the societal costs and benefits from urban vegetation in the United States are easily on the order of billions of dollars annually, the answer to this question likely is yes; however, the question remains to be investigated.

This assessment is the first step in developing a comprehensive understanding of the national urban forest resource and can assist in the development of comprehensive and adaptive management plans in both urban and exurban environments. As urbanization continues to expand, and urban populations increasingly dominate the social and political structure of the United States, understanding and managing urban forest resources will be a critical mechanism for connecting people with ecosystems in the 21st century.

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Literature Cited

Akbari, J; Davis, S.; Dorsano, S. [and others]. 1992. Cooling our communities: a guidebook on tree planting and light-colored surfacing. Washington, DC: U.S. Environmental Protection Agency.

Allen, L.; Sherfy, M. 1997. Show me ReLeaf: a unique partnership. In: Kollin, C., ed. Cities by nature's design: Proceedings, 8th national urban forest conference; 1997 September 17-20; Atlanta. Washington, DC: American Forests: 88-92.

Andresen, J.W.; Burban, L.L. 1993. Storms over the urban forest: planning, responding, and regreening—a community guide to natural disaster relief. Urbana, IL: University of Illinois, Urbana-Champaign, Department of Forestry. 94 p. In cooperation with: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry; Illinois Department of Conservation, Division of Forest Resources.

Barden, C. 1997a. Asian long-horned beetle questions and answers. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry.

Barden, C. 1997b. Asian long-horned beetle update. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry.

Barlow, S.A.; Munn, I.A.; Cleaves, D.A.; Evans, D.L. 1998. The effect of urban sprawl on timber harvesting. Journal of Forestry. 96(12): 10-14.

Bormann, B.T.; Cunningham, P.G.; Brookes, M.H. [and others]. 1994. Adaptive ecosystem management in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-341. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Bradley, G.A., ed. 1984. Land use and forest resources in a changing environment: the urban/forest interface. Seattle, WA: University of Washington Press. 222 p.

Bradshaw, M. 1995. Cool Dallas: a model for community involvement. In: Kollin, C.; Barratt, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 132-134.

Clark, J.R.; Matheny, N.P.; Cross, G.; Wake, V. 1997. A model of urban forest sustainability. Journal of Arboriculture. 23(1): 17-30.

Community Future Forum. 1998. Building an urban natural resources agenda for the 21st century. http://willow.ncfes.umn.edu//forum.

Coulombe, M.J. 1995. Sustaining the world's forests: the Santiago agreement. Journal of Forestry. 93(4): 18-21.

Cubbage, F.W.; O'Laughlin, J.; Bullock, C.S., III. 1993. Forest resource policy. New York: John Wiley and Sons. 562 p.

Dwyer, J.F. 1991. Economic value of trees. In: A national research agenda for urban forestry in the 1990's. Urbana, IL: International Society of Arboriculture: 27-32.

Dwyer, J.F. 1994. Customer diversity and the future demand for outdoor recreation. Gen. Tech. Rep. RM-252. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 58 p.

Dwyer, J.F.; McPherson, E.G.; Schroeder, H.W.; Rowntree, R.A. 1992. Assessing the benefits and costs of the urban forest. Journal of Arboriculture. 18(5): 227-234.

Dwyer, J.F.; Schroeder, H.W.; Louviere, J.J.; Anderson, D.H. 1989. Urbanites, willingness to pay for trees and forests in recreation areas. Journal of Arboriculture. 15(10): 247-252.

Dwyer, J.F.; Schroeder, H.W. 1995. The human dimensions of urban forestry. Journal of Forestry. 92(10): 12-15.

Ewert, A.W.; Chavez, D.J.; Magill, A.W., eds. 1993. Culture, conflict, and communication in the wildland-urban interface. Boulder, CO: Westview Press. 410 p.

Fischer, W.C.; Arno, S.F., eds. 1988. Protecting people and homes from wildfire in the interior West: Proceedings of the symposium and workshop; 1987 October 6-8; Missoula, MT. Gen. Tech. Rep. 251. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 213 p.

Forest and Rangeland Renewable Resources Planning Act. Act of Aug. 17, **1974.** 88 Stat. 476, as amended; 16 U.S.C. 1600-1614.

Frey, H.T. 1973. Major uses of land in the United States, summary for 1969. Agric. Econ. Rep. 247. Washington, DC: U.S. Department of Agriculture, Economic Research Service. 42 p.

Gangloff, D. 1995. The sustainable city. American Forests. May/June: 30-34, 38.

Geolytics, Inc. 1996. CensusCD™. East Brunswick, NJ. Data source: Census of Population and Housing, 1990: Summary Tape File 3 on CD-ROM [machine-readable data files]/prepared by the Bureau of the Census. Washington, DC: The Bureau [producer and distributor], 1992.

Gobster, P.H. 1995. Perceptions and use of a metropolitan greenway system for recreation. Landscape and Urban Planning. 33: 401-413.

Gobster, P.H. 1997. Chicago wilderness and its critics: the other side—a survey of arguments. Restoration and Management Notes. 15(1): 32-37.

Gobster, P.H.; Westphal, L.W. 1998. People and the river: perception and use of Chicago waterways for recreation. Chicago Rivers Demonstration Project Report. Milwaukee, WI: U.S. Department of the Interior, National Park Service, Rivers, Trails, and Conservation Assistance Program. 192 p.

Goodfellow, J. 1989. Trees and utilities. In: Rodbell, P., ed. Make our cities safe for trees: Proceedings of the 4th urban forest conference; 1989 October 15-19; St. Louis. Washington, DC: The American Forestry Association: 131-133.

Gregersen, H.; Lundgren, A.; Byron, N. 1998. Forestry for sustainable development: making it happen. Journal of Forestry. 96(3): 6-10.

Grey, G.W.; Deneke, F.J. 1986. Urban forestry. New York: John Wiley and Sons. 299 p.

Grove, M.; Vachta, K.E.; McDonough, M.H.; Burch, W.R., Jr. 1993. The urban resources initiative: community benefits from forestry. In: Gobster, P.H., ed. Managing urban and high-use recreation settings: Selected papers from the “Urban forestry and ethnic minorities and the environment” paper sessions at the 4th North American symposium on society and resource management; 1992 May 17-20; Madison, WI. Gen. Tech. Rep. NC-163. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 24-32.

Haack, R.A.; Law, K.R.; Mastro, V.C. [and others]. 1997. New York’s battle with the Asian long-horned beetle. Journal of Forestry. 95(12): 11-15.

Harris, R.W. 1983. Arboriculture. Englewood Cliffs, NJ: Prentice-Hall, Inc. 688 p.

Heisler, G.H. 1986. Energy saving with trees. Journal of Arboriculture. 12(5): 113-125.

Heisler, G.H; Grant, R.H; Grimmond, S.; Souch, C. 1995. Urban forests–cooling our communities? In: Kollin, C.; Barrat, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 31-34.

Kielbaso, J.J. 1990. Trends and issues in city forests. Journal of Arboriculture. 16(3): 69-76.

Knight, F.B.; Heikkenen, H.J. 1980. Principles of forest entomology. New York: McGraw-Hill Book Co. 461 p.

Küchler, A.W. 1969. Potential natural vegetation. Survey Map, Sheet 90. Washington, DC: U.S. Geological Survey.

Kuhns, M.; Ferenz, G.; Blahna, D. 1995. Effective community involvement in urban forestry programs. In: Kollin, C.; Barratt, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 184-187.

Laughlin, J.; Page, C., eds. 1987. Wildfire strikes home! The report of the national wildland/urban fire protection conference. [Place of publication unknown]: Books On Fire, Inc. 89 p.

Lee, K.N. 1993. Compass and gyroscope: integrating science and politics for the environment. Washington, DC: Island Press. 243 p.

Lein, J.N.; Buhyoff, G.J. 1986. Extension of visual quality models for urban forests. Journal of Environmental Management. 22: 245-254.

LeMaster, D.; Sedjo, R., eds. 1993. Modeling sustainable forest ecosystems. Washington, DC: American Forests, Forest Policy Center.

Lipfert, F.W. 1994. Air pollution and community health. New York: Van Nostrand Reinhold. 556 p.

Loomis, S. 1995. Revitalizing Baltimore: a model process for urban ecosystem management. In: Kollin, C.; Barratt, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 40-43.

Lotan, J.E.; Alexander, M.E.; Arno, S.F. [and others]. 1978. Effects of fire on flora: a state-of-knowledge review. In: National fire effects workshop; 1978 April 10-14; Denver, CO. Gen. Tech. Rep. WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service. 71 p.

Manion, P.D. 1981. Tree disease concepts. Englewood Cliffs, NJ: Prentice Hall, Inc. 399 p.

Maser, C.; Bormann, B.T.; Brookes, M.H. [and others]. 1994. Sustainable forestry through adaptive ecosystem management is an open-ended experiment. In: Maser, C. Sustainable forestry: philosophy, science, and economics. Delray Beach, FL: St. Lucie Press: 304-340.

McPherson, E.G.; Haip, R.A. 1989. Emerging desert landscape in Tucson. Geographical Review. 79: 435-449.

McPherson, E.G.; Luttinger, N. 1998. From nature to nurture: the history of Sacramento's urban forest. Journal of Arboriculture. 24(2): 72-88.

McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. 1994. Chicago's urban forest ecosystem: results of the Chicago urban forest climate project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 201 p.

McPherson, E.G.; Nowak, D.J.; Sacamano, P.L. [and others]. 1993. Chicago's evolving urban forest: initial report of the Chicago urban forest climate project. Gen. Tech. Rep. NE-169. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 55 p.

Miller, R.W. 1997. Urban forestry. Englewood Cliffs, NJ: Prentice-Hall, Inc. 199 p.

Mills, E.S.; Hamilton, B.W. 1984. Urban economics. Glenview, IL: Scott, Foresman and Company. 420 p.

Moll, G.; Berish, C. 1996. Atlanta's changing environment. American Forests. Spring: 26-29.

Nannini, D.K.; Sommer, R; Myers, L.S. 1998. Resident involvement in inspecting trees for Dutch elm disease. Journal of Arboriculture. 24(1): 43-46.

Nassauer, J.I. 1993. Ecological function and the perception of suburban residential landscapes. In: Gobster, P.H., ed. Managing urban and high-use recreation settings: Selected papers from the "Urban forestry and ethnic minorities and the environment" paper sessions at the 4th North American symposium on society and resource management; 1992 May 17-20; Madison, WI. Gen. Tech. Rep. NC-163. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 55-60.

Nassauer, J.I. 1997. Cultural sustainability: aligning aesthetics and ecology. In: Nassauer, J.I., ed. Placing nature: culture and landscape ecology. Washington, DC: Island Press: 65-83.

Neville, R.L. 1996. Urban watershed management: the role of vegetation. Syracuse, NY: State University of New York, College of Environmental Science and Forestry. 143 p. Ph.D. dissertation.

Nowak, D.J. 1991. Urban forest development and structure: analysis of Oakland, California. Berkeley, CA: University of California, Berkeley. 232 p. Ph.D. dissertation.

Nowak, D.J. 1993a. Compensatory value of an urban forest: an application of the tree-value formula. Journal of Arboriculture. 19(3): 173-177.

Nowak, D.J. 1993b. Historical vegetation change in Oakland and its implications for urban forest management. Journal of Arboriculture. 19(5): 313-319.

Nowak, D.J. 1993c. Remote sensing and urban forestry. In: 1992 Society of American Foresters national conference proceedings; 1992 October 25-28, Richmond, VA. Bethesda, MD: Society of American Foresters: 103-108.

Nowak, D.J. 1994. Urban forest structure: the state of Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago urban forest climate project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 3-18, 140-164.

Nowak, D.J.; Crane, D.E. [In press]. The urban forest effects (UFORE) model: quantifying urban forest structure and functions. In: Proceedings, 2d international symposium: Integrated tools for natural resources inventories in the 21st century; 1998 August 17-19; Boise, ID. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station.

Nowak, D.J.; Dwyer, J.F. 2000. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, J.E., ed. Handbook of urban and community forestry in the Northeast. New York: Kluwer Academic/Plenum Publishers: 11-25.

Nowak, D.J.; McBride, J.R. 1992. Differences in Monterey pine pest populations in urban and natural forests. Forest Ecology and Management. 50: 133-144.

Nowak, D.J.; McHale, P.J.; Ibarra, M. [and others]. 1998. Modeling the effects of urban vegetation on air pollution. In: Gryning, S.E.; Chaunerliac, N., eds. Air pollution modeling and its application XII. New York: Plenum Press: 399-407.

Nowak, D.J.; Rowntree, R.A.; McPherson, E.G. [and others]. 1996. Measuring and analyzing urban tree cover. Landscape and Urban Planning. 36: 49-57.

Nowak, D.J.; Sydnor, T.D. 1992. Popularity of tree species and cultivars in the United States. Gen. Tech. Rep. NE-166. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 44 p.

Oakland Tribune. 1923. Oakland hills' forest mantle all hand made. July 15.

Ossenbruggen, S.; Maller, L. 1997. The urban resources partnership: inter-governmental collaboration for community change. In: Kollin, C., ed. Cities by design: Proceedings, 8th national urban forest conference; 1997 September 17-20; Atlanta. Washington, DC: American Forests: 194-198.

Piotrowski, G. 1995. Revitalizing Baltimore and urban ecosystem policy at the state and local level. In: Kollin, C.; Barratt, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 158-161.

Pirone, P.P. 1972. Tree maintenance. New York: Oxford University Press. 574 p.

Raffetto, J. 1993. Perceptions of ecological restoration in urban parks. In: Gobster, P.H., ed. Managing urban and high-use recreation settings: Selected papers from the "Urban forestry and ethnic minorities and the environment" paper sessions at the 4th North American symposium on society and resource manage-ment; 1992 May 17-20; Madison, WI. Gen. Tech. Rep. NC-163. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 61-67.

Ross, L.M. 1994. Illinois' volunteer corps: a model program with deep roots in the prairie. Restoration and Management Notes. 12(1): 57-59.

Ross, L.M. 1997. The Chicago wilderness: a coalition for urban conservation. Restoration and Management Notes. 15(1): 17-24.

Sanders, R.A. 1984. Some determinants of urban forest structure. Journal of Urban Ecology. 8: 13-27.

Sanders, R.A. 1986. Urban vegetation impacts on the urban hydrology of Dayton, Ohio. Journal of Urban Ecology. 9: 361-376.

Schroeder, H.W. 1982. Preferred features of urban parks and forests. Journal of Arboriculture. 8(12): 317-322.

Schroeder, H.W. 1983. Variations in the perception of urban forest recreation sites. Leisure Sciences. 5(3): 221-230.

Schroeder, H.W. 1986. Estimating park tree density to maximize landscape esthetics. Journal of Environmental Management. 23: 325-333.

Schroeder, H.W. 1988. The experience of significant landscapes at the Morton Arboretum. In: Economic and social development — a role for forests and forestry professionals: Proceedings of the 1987 Society of American Foresters national convention; 1987 October 18-21; Minneapolis, MN. Bethesda, MD: Society of American Foresters: 378-381.

Schroeder, H.W. 1989. Environment, behavior and design research on urban forests. In: Zube, E.H.; Moore, G.L., eds. Advances in environment, behavior and design. New York: Plenum Press: 87-107.

Schroeder, H.W. 1998. Why people volunteer. Restoration and Management Notes. 16(1): 66-67.

Schroeder, H.W.; Anderson, L.M. 1984. Perception of personal safety in urban recreation sites. Journal of Leisure Research. 16(2): 178-194.

Schroeder, H.W.; Buhyoff, G.J.; Cannon, W.N., Jr. 1986. Cross-validation of predictive models for esthetic quality of residential streets. Journal of Environmental Management. 23: 309-316.

Schroeder, H.W.; Cannon, W.N., Jr. 1983. The esthetic contribution of trees to residential streets in Ohio towns. Journal of Arboriculture. 9(9): 237-243.

Schroeder, H.W.; Cannon, W.N., Jr. 1987. Visual quality of residential streets: both street and yard trees make a difference. Journal of Arboriculture. 13(10): 247-252.

Sexton, K.; Gong, H., Jr.; Bailar, J.C., III [and others]. 1993. Air pollution health risks: do class and race matter? Toxicology and Industrial Health. 9(5): 843-878.

Shore, D. 1997. Controversy erupts over restoration in Chicago area. Restoration and Management Notes. 15(1): 25-31.

Shprentz, D.S. 1996. Breath-taking: premature mortality due to particulate air pollution in 239 American cities. New York: Natural Resources Defense Council. 154 p.

Sommer, R. 1997. The value of resident participation in tree planting. Arborist News. 5(6): 43-44.

Sommer, R.; Leary, F.; Summitt, J.; Tirrell, M. 1994. Social benefits of resident involvement in tree planting: comparisons with developer-planted trees. Journal of Arboriculture. 20(6): 323-328.

Sommer, R.; Summitt, J.; Leary, F.; Tirrell, M. 1995. Social and educational benefits of a community shade tree program: a replication. Journal of Arboriculture. 21(5): 260.

Stout, D. 1996. Brooklyn trees to be felled to stop invading beetles. New York Times. December 25; Sect. B: 3.

Tschantz, B.A.; Sacamano, P.L. 1994. Municipal tree management in the United States. Kent, OH: Davey Resource Group. 71 p.

Ulrich, R.S. 1986. Human response to vegetation and landscapes. Landscape and Urban Planning. 13: 29-44.

U.S. Department of Agriculture, Forest Service. 1982. An analysis of the timber situation in the United States: 1952-2030. For. Resour. Rep. 23. Washington, DC. 499 p.

U.S. Department of Agriculture, Forest Service. 1989. Draft 1990 RPA program. Washington, DC. 186 p.

U.S. Department of Agriculture, Forest Service. 1994. Forest insect and disease conditions in the United States 1993. Washington, DC. 73 p.

U.S. Department of Agriculture, Forest Service. 1997a. FIA database retrieval system. http://www.srsfia.usfs.msstate.edu/scripts/ew.htm.

U.S. Department of Agriculture, Forest Service. 1997b. Forest health protection: the Asian longhorned beetle (*Anoplophora glabripennis*). http://www.fs.fed.us/foresthealth/exotics/asianlh.html.

U.S. Department of Agriculture, Forest Service. 1997c. Forest land distribution data for the United States. http://www.srsfia.usfs.msstate.edu/rpa/rpa93.htm.

U.S. Department of Agriculture, Forest Service. 1998a. Asian longhorned beetle in Chicago: update on the Northeastern Area State & Private Forestry response. http://willow.ncfes.umn.edu/beetlechicago/beetlechicago09-18-98.htm.

U.S. Department of Agriculture, Forest Service. 1998b. Urban national forest homepage. http://www.fs.fed.us/recreation/permits/urban/.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1994. National resources inventory training modules. Washington, DC. 130 p.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1995. 1992 national resources inventory [machine-readable data files]. Fort Worth, TX.

U.S. Department of Commerce, Bureau of the Census. 1992a. 1990 census of population. CP-1-1B: General population characteristics: metropolitan areas. Washington, DC.

U.S. Department of Commerce, Bureau of the Census. 1992b. 1990 census of population. CP-1-1C: General population characteristics: urbanized areas. Washington, DC.

U.S. Department of Commerce, Bureau of the Census. 1992c. Census of population and housing, 1990: Summary tape file 3 on CD-ROM [machine-readable data files]. Washington, DC.

U.S. Department of Commerce, Bureau of Census. 1994a. 1994 Tiger/Line® files [machine-readable data files]. Washington, DC.

U.S. Department of Commerce, Bureau of Census. 1994b. Geographic areas reference manual. Washington, DC: Economics and Statistics Administration, Bureau of the Census.

U.S. Department of Commerce, Bureau of the Census. 1997. Previous metropolitan area definitions. Washington, DC. http://www.census.gov/population/www/estimates/metro-city/maupdate.txt.

U.S. Department of Commerce, Bureau of the Census. 1998a. Annual inmigration, outmigration, net migration, and movers from abroad for regions: 1980-1997. Washington, DC. http://www.census.gov/population/socdemo/migration/tab-a-2.txt.

U.S. Department of Commerce, Bureau of the Census. 1998b. Inmigration, outmigration, and net migration for metropolitan areas: 1985-1997. Washington, DC. http://www.census.gov/population/socdemo/migration/tab-a-3.txt.

Wear, D.N.; Liu, R.; Foreman, J.M; Sheffield, R. 1999. The effects of population growth on timber management and inventories in Virginia. Forest Ecology and Management. 118: 107-115.

Webster, H.H. 1993. Some thoughts on sustainable development as a concept, and as applied to forests. The Forestry Chronicle. 69(5): 531-33.

Westphal, L.M. 1994. Urban forestry volunteers and effective outreach. In: Gobster, P.H., ed. Managing urban and high-use recreation settings: Selected papers from the “Urban forestry and ethnic minorities and the environment” paper sessions at the 4th North American symposium on society and resource management; 1992 May 17-20; Madison, WI. Gen. Tech. Rep. NC-163. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 436-441.

Westphal, L.M. 1995a. Birds do it, bees do it, but why do volunteers do it? A look at motivations. In: Stearns, F.; Holland, K., eds. 1995. Proceedings, Midwest oak savanna conference; 1993 February 20; Chicago. Chicago: U.S. Environmental Protection Agency.

Westphal, L.M. 1995b. Participating in urban forestry projects: how the community benefits. In: Kollin, C.; Barratt, M., eds. Inside urban ecosystems: Proceedings, 7th national urban forest conference; 1995 September 12-16; New York. Washington, DC: American Forests: 101-103.

Westphal, L.M. 1997. If we can make it here we can make it anywhere: a case study of urban ecosystem management. In: Caldwell, L.; Mon, S., eds. Integrating social science and ecosystem management: a national challenge; 1995 December 12-14; Helen, GA. Gen. Tech. Rep. SRS-17. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 44-48.

Westphal, L.M.; Childs, G.M. 1994. Overcoming obstacles: creating volunteer partnerships. Journal of Forestry. 92(10): 28-32.

Westphal, L.M.; Gobster, P.H. 1995. Legacy of the Clean Water Act: impacts of water quality on urban river recreation. In: Proceedings, 4th international outdoor recreation and tourism trends symposium and the 1995 national recreation resource planning conference; 1995 May 14-17; St. Paul, MN. St. Paul, MN: University of Minnesota College of Natural Resources; Minnesota Extension Service: 620-624.

Wiersum, K.F. 1995. 200 years of sustainability in forestry: lessons from history. Environmental Management. 19(3): 321-329.

Zhu, Z. 1994. Forest density mapping in the lower 48 states: a regression procedure. Res. Pap. SO-280. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station Research Paper. 11 p.

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